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ABSTRACT

It is presumed that those reading this book presently own and operate a central control and monitoring system (CCMS) or plan to implement one in the near future. One objective of this workbook is to present useful knowledge from case histories of members of the Association of Physical Plant Administrators of Universities and Colleges as well as current information about the state of the art and of a rapidly changing, technology-oriented industry. Chapters cover justification for a CCMS, basic designs and considerations, planning and economic analyses, equipment selection, procurement practices and improvements, installation, personnel and training, operation and maintenence, maintenence and troublesnooting, and adapting systems to energy management. (Author/IRT)

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Central Control and Automation Systems

A Management and Procurement Handbook

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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EA 011 419

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FOREWORD

This publication is a revision and consolidation of the text of two Central Control and Automation Systems Workbooks developed by The Association of Physical Plant Administrators (APPA) in 1976 and 1977. The original workbooks were developed in conjunction with seminar programs dealing with the procurement and management of Central Control and Automation Systems.

An APPA Seminar Advisory Committee selected the topics discussed at the seminars and chose a group of experts as speakers. The speakers were responsible for developing their presentations and for writing specific chapters of the original workbooks.

Due to a continued demand for copies of the workbooks and a depleted supply, the APPA Energy Conservation Committee recommended their revision into this publication. This publication differs only in the improvement made through consolidation, editing and retyping into a single-spaced format.

APPA wishes to express appreciation to the original workbook authors, Seminar Advisory Committees and the APPA Energy Conservation Committee for their contributions and assistance. A special thanks is offered to the Energy Task Force for its continued support of the development of the publication and to Maggie Coons, who was the principal editor of this revision.

Richard W. Anderson, Jr.
Director of Special Programs

CHAPTER I

INTRODUCTION

BACKGROUND

WHY CENTRAL CONTROL?

OBJECTIVES

BASIC FUNCTIONS OF CENTRAL CONTROL

CHAPTER I

INTRODUCTION

Background

The concept of centralized control is almost universally accepted as the most efficient means of controlling and operating today's large buildings and industrial plants, which range from single buildings with as little as 100,000 square feet to an entire university campus with millions of square feet under roof and presumably under control.

Central control may be as simple as a centrally located start/stop switch for a remotely located exhaust fan in one building, or may involve a complex computer-operated system to collect, process and display data and perform numerous functions automatically for entire campuses located many miles away from the physical plant office. The most simple forms of central control are:

- warning lights from remotely located equipment
- central start/stop station
- central temperature indication

At the opposite end of the scale, the state of the art embraces fully computerized building systems with the computer supervising:

- building automatic stop/start
- alarm monitoring
- alarm logging
- trend logging
- fire management
- power management
- door security
- maintenance instruction programming

Why Central Control?

As buildings, automatic processes and controlled systems grew larger and more spread out, it became physically impossible for operators to successfully monitor the systems. The logic demand of the system required operators to move rapidly from one place to another. Ultimately, this became inefficient. Centralizing limits, alarm and logic functions enabled one operator to quickly sense and command various systems and saved money. For example, it became economically justifiable to start up and shut down a system with 50 air-handling units and associated pumps, boilers or refrigeration machines.

Before 1970, Central Control and Monitoring Systems (CCMSs) were generally difficult to justify on the basis of return on investment. Two factors have contributed to a drastic change in this scenario. First, the technological advancements in computer system design, especially in the areas of microcircuitry and digital transmission, have substantially lowered the cost of central control equipment while simultaneously improving performance and reliability. The second factor influencing the wide acceptance of CCMSs is the painful rise in the cost of energy. No other single factor has had more influence in creating the building automation and energy management stampede than the Arab oil embargo and the resulting quadrupled cost of oil.

In general, CCMSs are adopted for one or more of the following reasons:

1. Reduced operating cost: It is usually possible to pay back the original investment within five years through reduced utility cost and manpower savings.
2. Improved performance: Maintaining a high level of equipment performance is often difficult or impossible without a CCMS. With CCMS, early detection of pending malfunctions is possible as well as programmed maintenance based on operating time and characteristic criteria, not rote.
3. Life safety: CCMS permits integration of fire alarm, smoke detection and security systems into the overall automation philosophy. CCMS is an excellent way of sensing, diagnosing, making decisions and implementing appropriate emergency actions.

Regardless of the reasons offered, the name of the game is saving dollars. The conservationists may be turned on by "reducing the consumption of depletable resources" or may favor anything that reduces the environmental pollution level. The physical plant administrator usually cannot entertain such ethereal objectives. His annual operating budget does not have a fat inflation factor that is wired to the whimsical pricing policies of the OPEC consortium.

In 1973, in the height of the trauma of the gasoline shortages, the University of Maryland prepared a preliminary analysis to provide justification for a central budget request for a CCMS. The analysis is included in Appendix A. You will note that of the three energy cost projections developed, low, medium and high, the actual use three years later very nearly approximated the "high" estimate of energy cost inflation. With this rate of energy inflation, the projected five-year energy cost "savings" or "cost avoidance" is $3.8 million. The "high" estimates of three years ago represent the actual situation of today and tomorrow. It is easy to see why the 15 to 20 percent energy reduction usually effected by a CCMS makes it an outstanding investment in today's market. However, if you are fortunate enough to obtain the capital funds for the initial investment, how can you be assured of the 15 to 20 percent energy reduction? We will pursue the answer to this question together.

Objectives

It is presumed that those reading this book presently own and operate CCMSs or plan to implement one in the near future. One objective of this workbook is to present useful knowledge from case histories of members of the Association of Physical Plant Administrators of Universities and Colleges (APPA) as well as current information about the state of the art of a rapidly changing, technology-oriented industry.

Often, purchasing departments and government agencies mistakenly believe that a CCMS is a self-contained, self-sufficient, expensive machine that when purchased from the low bidder is merely plugged into the nearest duplex receptable and from then on performs its miracles. Many of us know of instances where this type of philosophy has been applied and we know what the outcome was--another bad system was born. We will attempt to examine this "miracle-working" machine or system to ascertain what it does and does not do and what is required to make it do what you expect of it.

Most purchasers of CCMSs do not start out with a complete campus-wide system. The usual constraint is dollars. However, once the system is in and functioning, and, hopefully, saving money, the need arises to expand the system and complete the original project or to pick up new buildings. It is at this point that you really find out what you bought. Perhaps you didn't get the full-size chassis; you got the expandable starter set, better known as the "Contractor's Special." To expand the "Contractor's Special" can mean almost a repeat of the original investment, not merely an inexpensive extension. Together, we will learn from the experience of others and by study of available information how to avoid the pitfalls of being sold short.

Basic Functions of Central Control

The underlying principles of automatic control involve:

- savings in personnel cost
- utilizing key personnel more effectively
- reducing the number of personnel hours per control point

Obviously, the primary value of central control is the savings in operating costs by reducing the number of personnel. Typically, an economic analysis of a large control system shows a pay-out period of between three and seven years. However, it should be kept in mind that the concept of central control can be based upon a "building block principle."

The most elementary function performed by the central control system is to alert the building operator when something is wrong or to enable him to remotely control a given device that is distant from the console. This means that the basic, essential functions of central control include alarm sensing and remote stop/start.

Typically, alarms can be shown by back-lit nameplates or pilot lights with an audible alarm. When a given controller goes beyond its control point, a sensor at the central point location transmits an alarm signal back to the central panel. The operator, after silencing the audible features, proceeds to act upon the information.

The next step in the basic central control system is for the operator to determine the "value" of the variable in alarm. This would usually be done by the use of a temperature-indicating device. These are many such devices, including thermocouples, resistance thermometers, pressure analog thermometers and digital thermometers. However, in all events the operator becomes aware of the value of the point in alarm.

Since many points in a large system can go into alarm simultaneously, it is convenient to provide a recording device to record the alarms and the times at which they occurred. The operator can then deal with the alarms in a programmed sequence.

Typically, each sensing point in an electronic system is scanned several times per minute. The central alarm scanner "locks" each control point in sequence and reads its value. This value is then transmitted to the central panel if it is in an alarm condition.

To assist the operator in diagnosing the problem, we can provide a symbolic representation of the system under consideration. For example, a picture of an air-handling system can be displayed on a back-lit nameplate, a projection screen, a television screen or an engraved system diagram. Each alarm point is then given a "code number" which can be identified on the system schematic. The operator is then aware which point is in alarm and the value of that point. He is then in a better position to take action.

He can view several other points on his schematic. By checking the temperature indicator, he can discover if other points are normal or in alarm and determine the trouble point in the system.

An alarm printer can be added to record the times at which alarms occurred. Alarm printers can be used by management for preventive maintenance planning. If a system or air-handling unit is giving consistent trouble or malfunctioning at odd hours, it is possible to log the operation of that system by means of a logging printer. This is a device which accepts the point value of the system under consideration and prints these at given intervals of time. The time intervals may range from once every 60 seconds to once every 24 hours.

CHAPTER II

JUSTIFICATION FOR CENTRAL CONTROL SYSTEMS

METHODS OF REDUCING POWER
- Time Cycling
- Demand Limiting and Methods of Charging for Electric Power
- Metering
- Power Management

CHAPTER II

JUSTIFICATION FOR CENTRAL CONTROL SYSTEMS

Traditionally, Central Control and Monitoring Systems (CCMSs) had been justified on the basis of savings in labor. In recent years, however, particularly as a result of the energy crisis, managers have become aware of the impact of increased electric power costs on their operating budgets. CCMSs offer a way of reducing and controlling these electric power costs.

Methods of Reducing Electric Power Usage

Several fundamental methods of reducing the usage of electric power and thereby the total electric bill are:

- time cycling
- demand limiting
- power management

Time Cycling

The concept of "time cycling" is to shut off equipment when it is not needed. This may sound elementary, but as a practical matter, the building operator is confronted with an enormous task of analyzing the loads on any given day to determine the optimum start times, run times and stop times. The obvious solution is some type of time-cycling device, either a time clock or a central program controller into which the optimum start times have been previously set.

Time clocks are inexpensive to buy and install; however, they are relatively inflexible. In order to change the sequence of a time clock, one must physically adjust the cams within the device. For many applications, however, time clocks will suffice.

Program controllers, when keyed to centralized start/stop offer the operator a means of starting one or more motors simultaneously, runing them for variable lengths of time and stopping them when desired. The time that any motor starts can be easily varied from the central point, and allowances can be made for weekends and holidays.

Demand Limiting and Methods of Charging for Electric Power

Because of the method in which utility companies bill for power, it is advantageous to limit the demand to a reasonable maximum. Devices are available that can sense a preset demand limit and then selectively switch off electric loads when that present demand is exceeded. These devices are called demand limiters.

Most public utilities charge their customers for both "energy" and "demand."

Energy charges run in excess of two to three cents per kilowatt-hour. Kilowatt-hours are totaled during the billing period, usually a month, and then multiplied by the current energy rate. The result is a total energy charge for that month.

Demand is based upon the maximum level at which energy is consumed during a "demand interval." A demand interval is usually 15, 30 or 60 minutes. The demand is calculated by averaging the total kilowatt-hours used in any demand interval.

It is important to realize that instantaneous demands, such as the starting of a refrigeration machine, do not determine the peak demand during that month.

During a billing month, the average load consumed during each demand interval is determined and the highest average load in that month becomes the demand for that month. If a building consumes a disproportionate amount of power during any 30-minute period, then that 30-minute period sets the demand billing for that month. It becomes obvious that we must control demand and spread it equitably over an entire month rather than sustain sharp peaks during a given day or hour.

Metering

Most public utilities provide each customer with one totalizing meter. Generally, multiple metering is not used. An

electric meter is a device which integrates the supply voltage, the time and the instantaneous current flowing to produce the kilowatt-hours consumed during the billing month.

Most demand meters have a set of electrical contacts associated with the rotating armature of the meter, which cause a contact closure or pulse after several revolutions of the armature. In this manner, each pulse represents a number of kilowatt-hours during a given time interval. These pulses are then recorded on a circular chart, punched paper tape or magnetic tape.

Examination of the record at the end of the month yields a demand interval during which the maximum number of pulses occurred, thereby setting the maximum demand for that month.

Power Management

The concept of power management is an extension of the demand-limiting technique. Instead of limiting the peak demand in any given billing period, power management implies the limiting of demand in each time interval to a preprogrammed maximum. Power management, therefore, saves money both by limiting peak demand and also by reducing the energy usage during each time interval.

Since energy management implies a reduction in the use of electric power, there is generally a reduction in comfort or benefits of some sort when the use of power is reduced.

In a typical energy management program, wasteful consumption points are first determined and eliminated. The next step is to decide how much the beneficial use of electric power can be reduced while suffering the resulting lack of comfort or convenience.

For example, management may decide to shut off elevators in low-rise buildings during off-peak periods. A properly managed energy program will create a "trade-off" between hardship and sacrifice and available capital and energy resources.

Computerized power management systems offer building managers the ability to reduce power consumption somewhat beyond that necessary or tolerable by the building occupants. Once this point is reached, one can back off on load reductions while maintaining the entire system under optimum control. This is the concept of power management.

CHAPTER III

BASIC DESIGNS AND CONSIDERATIONS

INTRODUCTION

AUTOMATIC CONTROL

AUTOMATION SYSTEM

TYPES OF CONTROL SYSTEMS

CENTRAL CONTROL AND MONITORING SYSTEM
- Input Devices
- Output Devices
- Data Collection Panels (DCP)
- Central Equipment
- Data Transmission Links

FLEXIBILITY
- General Considerations
- CPU Memory Changes Made from Keyboard, not Requiring a New Tape

SOFTWARE PROGRAMS
- Executive Program and Operating Instructions
- Stop/Start Program
- Load Rotation Program
- Load Shedding Program
- Reset Programs
- Alarm Programs
- Optimization Programs
- Power Factor Improvement
- Load and Performance Profiles
- Maintenance Management
- Lighting Control
- Fire/Security Alarm Programs
- Watch Tour Program
- Recommendations

CHAPTER III

BASIC DESIGNS AND CONSIDERATIONS

Introduction

An example of a fundamental automatic control system is a man controlling a valve. He visualizes the flow rate and adjusts the valve accordingly. In this example, the man is the controller, the valve is the controlled device, and the water is the medium.

Obviously, we can replace the man with an automatically controlled device. For example, we could substitute a pressure-reducing valve for the man and manual valve combination. In this case, we would have an open-loop control system. It is open-loop because the pressure on the reduced side in no way affects the controller. We could substitute a closed-loop control system by providing a sensor on the downstream side. This device would monitor the pressure of the reduced fluid and transmit a signal back to the controller, readjusting it as necessary in order to provide a constant reduced pressure.

Fig. 1 shows a fundamental diagram of a control system. The system consists of a controller, a control device and the control medium. A controller is a device that regulates the controlled variable. These variables can be temperature, pressure, humidity, flow, voltage or current. These may be combined into a control signal. A control device is usually a valve, damper, relay, motor starter or fan.

Automatic Control

Automatic control is defined as any system in which a controlled device has been substituted for constant surveillance by a human. In most automatic systems, the controlled variable does not allow itself to be regulated constantly over a 24-hour, 365-days-per-year period.

Generally, the controlled variable must be cycled in some manner. For example, cycling can be day and night or weekends, in response to outside air temperature changes.

Therefore, it is convenient to provide a control interrupt to enable the process to be started and stopped at will. The control interrupt can be a switch, relay, valve or any other device that will separate the controller from the controlled device. When many controllers are required, such as at a campus, it is convenient to group the control interrupt at a central point. This enables one person to monitor, start and stop many control devices.

To alert the operator, it is also customary to transmit a signal from the remote control point to reflect the status of the control device. Control signals can be pilot lights, pressure gauges, analog signals or other variables that represent the status of the control device.

Automation System

Automation can be thought of as an automatic control system to which some form of preprogrammed logic has been added. This logic is programmed to provide action limits that initiate readjustment or corrective measures and, if necessary, provide alarm and shutdown.

For example, a typical automatic control system is illustrated by a man driving an automobile along a flat road at 50 miles per hour. If he does not possess automation, then he does not respond to unforeseen obstacles such as other cars or bridges. If he does possess automation, then he will sense an alarm condition and react to readjust the control system to a "normal" or "off" condition. Once the alarm condition has ceased, he can restart the system and maintain automatic control once again.

Types of Control Systems

Control systems can generally be classified in major groups as follows:

1. Self-contained systems: These are devices such as thermal expansion valves, flame-sensing thermopiles and water-regulating valves. These are usually spring set and spring controlled.

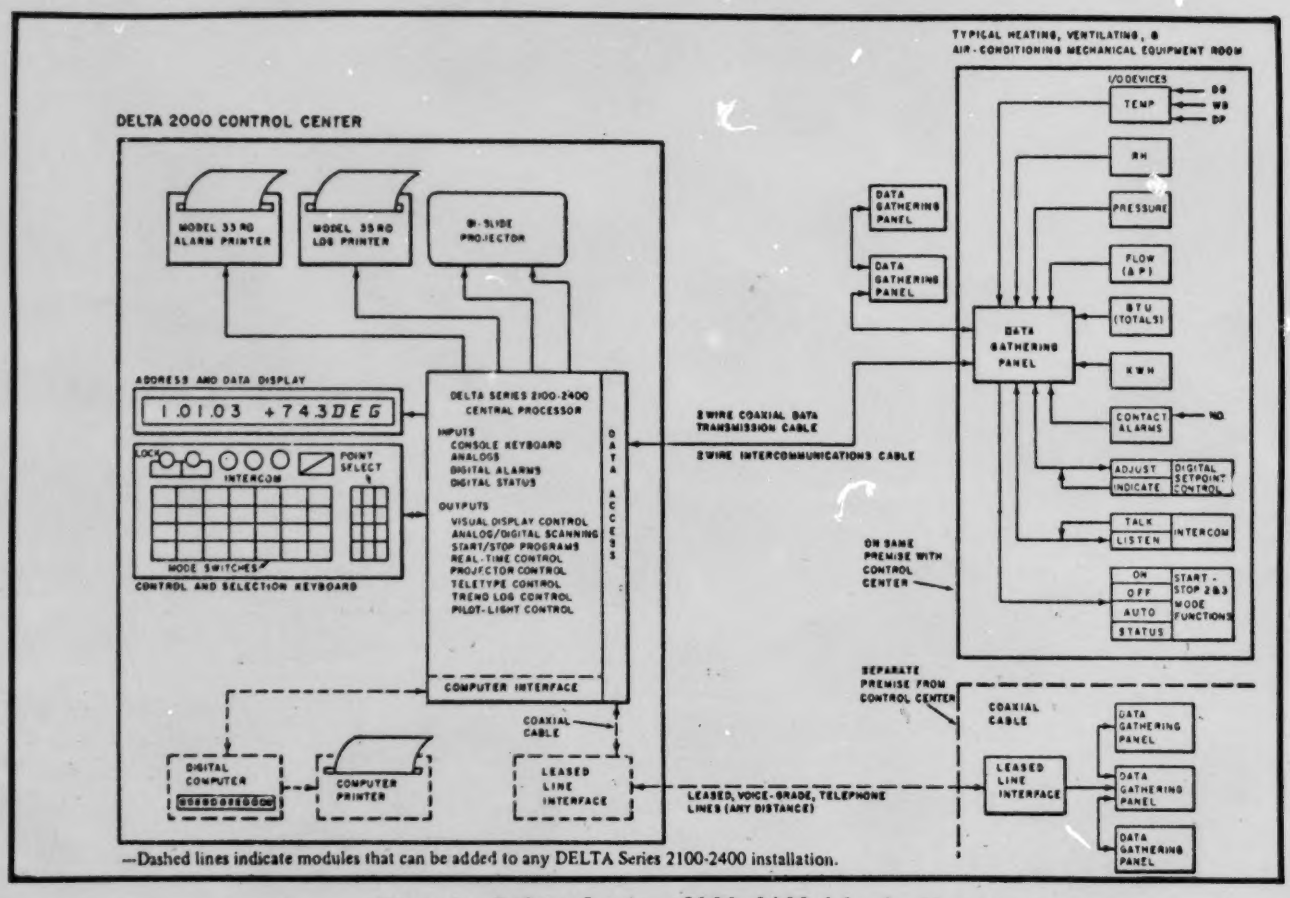

Fig. 1--Delta Series 2100-2400 block diagram

2. Pneumatic systems: These utilize compressed air at 20 pounds per square inch, which is varied as required by controllers to the controlled device.

3. Hydraulic systems: These systems function by varying fluid, pressure and volume. These are normally used for high-pressure, high-power systems such as cranes, tractors or earth-moving equipment.

4. Electric systems: These utilize an electric potential such as 16 volts, which can be varied or switched in order to control the controller.

5. Electronic systems: These use small electrical potentials, usually millivolts, which are then amplified at the control device.

6. Electronic pneumatic systems: These utilize compressed air for operation of the control device that is varied by a "transducer," which is a device for converting one signal to another. The transducer in turn is positioned by a sensor. For example, a pneumatic transducer converts a sensed pneumatic signal of three to five pounds into a control signal of zero to 15 pounds per square inch. An electronic transducer converts a five- to 10-millivolt signal into a pneumatic control signal from five to 10 pounds per square inch. In this way, a transducer should be thought of as an amplifier and a signal converter.

Central Control and Monitoring System

A basic building automation system, or Central Control and Monitoring System (CCMS), is shown in Fig. 2.

The system consists of five general types of components:

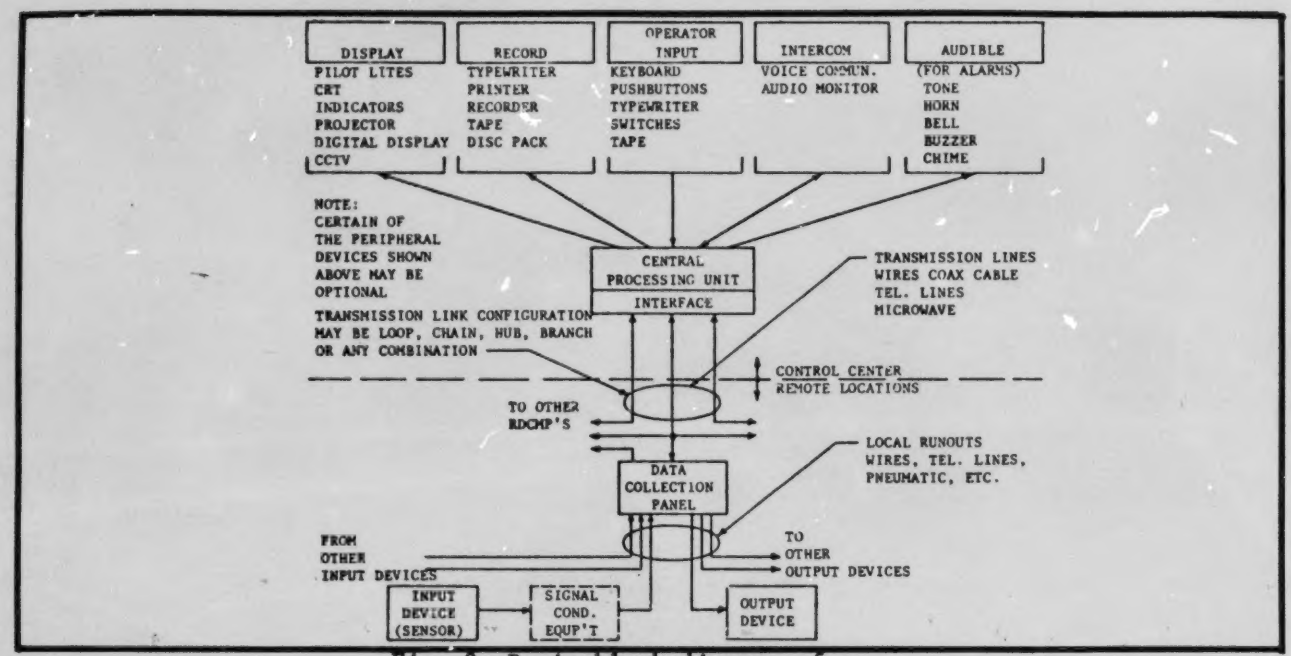

Fig. 2--Basic block diagram of a Central Control and Monitoring System

Input Devices

1. Sensors: All input devices that measure the condition of a variable are sensors. A sensor is a device that senses the point value of a given variable such as temperature, pressure, velocity or fluid flow. The data are transmitted throughout the system at high speed. The accuracy and reproducibility of a CCMS depends upon each segment of the chain and, in particular, upon the accuracy of the input from each sensing point.

   Sensors are located at each point in the system from which information is required. For example, we would locate temperature sensors at the entering and discharge points of an air-handling unit.

   The signal from any input device will fall into one of the following categories:

   a. Analog: a continuously variable signal that bears a known relationship to the value of the measured variable. Examples: a thermocouple measures temperature, and the signal is a nonlinear voltage; a resistance temperature device (RTD) measures temperature, and the signal is an electrical resistance

   b. Binary: an input signal equivalent to an electrical contact (switch) that only can be in an open or a closed position, as determined by a predefined condition. Examples: firestat, door contacts, slow switch and motor-starter auxiliary contact

   c. Codes: a combination of contact inputs in a defined format. Examples: badge reader, totalizer or counter; and keyboard

   d. Audio: microphone input to the intercom system

2. Signal conditioner: This is a device, which may be required on some types of analog inputs, that converts or amplifies the analog signal from a sensor to a different type of signal. The signal can then be used by a controller or transmitted over some distance to a Data Collection Panel (DCP), transmission system, and/or cen-

tral processor. It is frequently called a transducer or converter. The output of the signal conditioner normally is analog; in certain cases it may be a digital signal, such as with a relay, an analog/digital converter or a resistance-to-period transducer. Examples: differential pressure-to-current transducer (P/I), thermocouple temperature transmitter (TC/I), and resistance-to-period transducer.

Output Devices

A remote output device provides a means of converting a command instruction, appearing at the DCP, into a signal suitable for performing an operational function on external equipment. Output signals are classified similarly to input signals.

1. Binary: operation by the CCMS of the equivalent of an electrical contact (switch) to change the status of assigned equipment. Examples: motor on/off control; lighting control; mode switching, i.e., day/night; valve or damper open/closed control; and test and reset of fire alarm or security transmitters
2. Analog: provides an output signal of a continuously variable nature (electric or pneumatic) that is capable of proportional reset of external equipment. The signal may be true analog (voltage, current or air pressure) or it may be digitized to represent analog values. Examples: reset of the set point of a local controller and direct positioning of a modulating valve or damper
3. Codes: a combination of contact outputs in a defined format to perform a specific function. Example: operation of remote to printer using ASCII code
4. Audio: speaker operation for intercom system

Data Collection Panels (DCPs)

1. Data-gathering panels are central collection points where information from various sensors, usually in a radial array, is gathered, sorted, coded and arranged for transmission to a central processing point. These remote enclosures, which have been given many different names by various manufacturers (see glossary), act as termination points for the remote ends of the transmission links and for connections to the remote input and output devices in the vicinity.
2. Typically, a data-gathering panel would contain the various start/stop code modules, reset modules and other preprogrammed logic modules that react to signal input from remote points. Actual equipment, circuitry and functions of a DCP vary widely with the system and manufacturer, but some typical functions include: connection terminations for input/output (I/O) runouts, connection terminations for transmission links, address storage and recognition logic, command interpretation logic, multiplexing logic, transmitter and receiver, power supply, transmission line interface, data-buffering and conversion capability, timing control and modem.

   Since the signal character of a sensor is normally of an analog or contact closure nature, the data-gathering panels contain an analog-to-digital conversion unit. The purpose of this unit is to transform the signal character of the sensor into a binary code that can be transmitted at high speed on the transmission network. The characteristics of binary code are simple, consisting of a series of 1s and 0s arranged in a particular code and are therefore, susceptible to high-speed transmission without error.
3. Each DCP has one or more unique addresses that it must recognize

and/or transmit when communicating with the central processor. It must also interpret commands from the central processor and perform appropriate requested transmission of input data and/or output functions.

Central Equipment

1. Interface provides a connection point and necessary conversion of signals between the central processor and the transmission links for I/O with the DCPs.

2. The central processing unit (CPU) is a collection of equipment at the central control room containing the logic for management of the control system. The CPU receives signals from the transmission network, decodes them and utilizes them for information purposes. A CPU can be of the preprogrammed logic type or of the computer type. It has the ability to process all data in an orderly fashion and control the timing and flow of information to and from other elements of the system. It contains the interface with the operator (i.e., a console or keyboard). If a digital computer with a main memory is part of the system, it is generally regarded as a component of the CPU.

   When the sensor transmits, it means that the particular point in question has exceeded its preprogrammed list. The signal triggers a circuit in the CPU, which causes the CPU to move into an alarm condition. When the operator perceives and acknowledges the alarm, he "switches off" the transmitted signal or monitors it from time to time to see if it still remains in an alarm condition. Once the alarm condition has been removed, the sensor ceases to transmit, and, therefore, the CPU ceases to indicate an alarm condition at that point.

   In addition, the CPU contains the manual input capability to the system, normally a keyboard. By punching in a given code, the operator may address the sensing points in question. Each sensing point alarm device and controller has a unique address. It is generally not possible to address multiple points with the same code.

3. Peripheral devices are auxiliary I/O units (frequently optional) associated with the central processor.

   a. Typewriters

      (1) RO--"read only" printer: used to record processor's output data

      (2) KSR--"keyboard, send/receive" printer: The keyboard is used to send data to the processor (programming). The receiver portion is used to record processor output data.

      (3) ASR--"automatic send/receive" set: the same as KSR, with the addition of a paper-tape punch and reader

   b. Printers are for output only; they may vary in speed and format. Speeds range from 10 characters a second to several hundred lines a minute. The format of the printouts varies greatly, and may be on three-inch-wide paper tape or eight- or eleven-inch-wide (and wider) printed pages.

      Normally two types of printers are used. One printer records the alarm conditions in the system and is called the "alarm printer." The other is a "data printer" that records the logging information.

      The alarm printer is normally arranged to record only those alarm conditions that management considers significant. Thus, at the beginning of each shift the operator is able to determine the points that were in alarm, analyze those conditions and prepare corrective action.

The data printer is keyed to record information that is normally logged by the operator during a normal shift. Such conditions as chilled water leaving temperature, fan status and door security are logged on the logging printer. This gives management a summary of the condition of the facility at any given time and also prepares an overall summary of the status at the end of each shift.

c. Displays

(1) Cathode ray tube (CRT), display only: The CRT is a device that allows the information from the CPU to be displayed on a visual panel. Normally, the addition of a CRT to the system requires the addition of a computer. This is because a preprogrammed logic CPU does not have the capabilities to transform a signal into anything but a preprogrammed numeric piece of information.

(2) CRT display plus keyboard for input

(3) Digital data display

(4) A 35mm slide or filmstrip projector is normally furnished and consists of an industrial-type slide projector and screen, together with slides of the various components of the system. For example, when the operator realizes that air-handling unit (AHU) No. 6 is moving into an alarm condition, he is able to select a slide of AHU No. 6 and display it on the projector. The slide will show the configuration of the system in question, as well as the location and limit values of the alarm point in question. This, in turn, enables the operator to analyze the problems and to take corrective action.

(5) Pilot light displays

(6) System displays: a combination of 35mm graphic display surrounded by an array of several digital value displays and two arrays of pilot lights to indicate operating status and alarm conditions

d. Paper-tape reader and/or punch

e. Magnetic tape I/O equipment

f. Bulk memory: The chip, drum, disc or disc pack associated with a computer is sometimes considered to be part of the CPU.

Data Transmission Links

1. Data collected from and commands issued to remote points are sent to and from the CPU via transmission links. These transmission links take a wide variety of forms depending upon project requirements. Typical configurations are shown in Fig. 3.

2. Generally speaking, proprietary transmission links will be installed within any single building as part of the building automation contract. For multibuilding projects, proprietary leased line or a combination of both types of transmission links may be used. Proprietary transmission links consist of special cables required by the particular automation system being installed. These range from twisted shielded pairs to multiconductor and coaxial cables. Twisted pairs are used for voice and analog signals, multiconductor cables are used for parallel-type signal multiplexing, and coaxial cables are used for serial-type signal multiplexing.

3. Leased transmission links are telegraph-grade or voice-grade telegraph lines that can be rented from the local telephone utility as two-wire (usually half-duplex) or four-wire (full-duplex) circuits. Data are transmitted serially on these lines at specified speeds in bits per second, referred

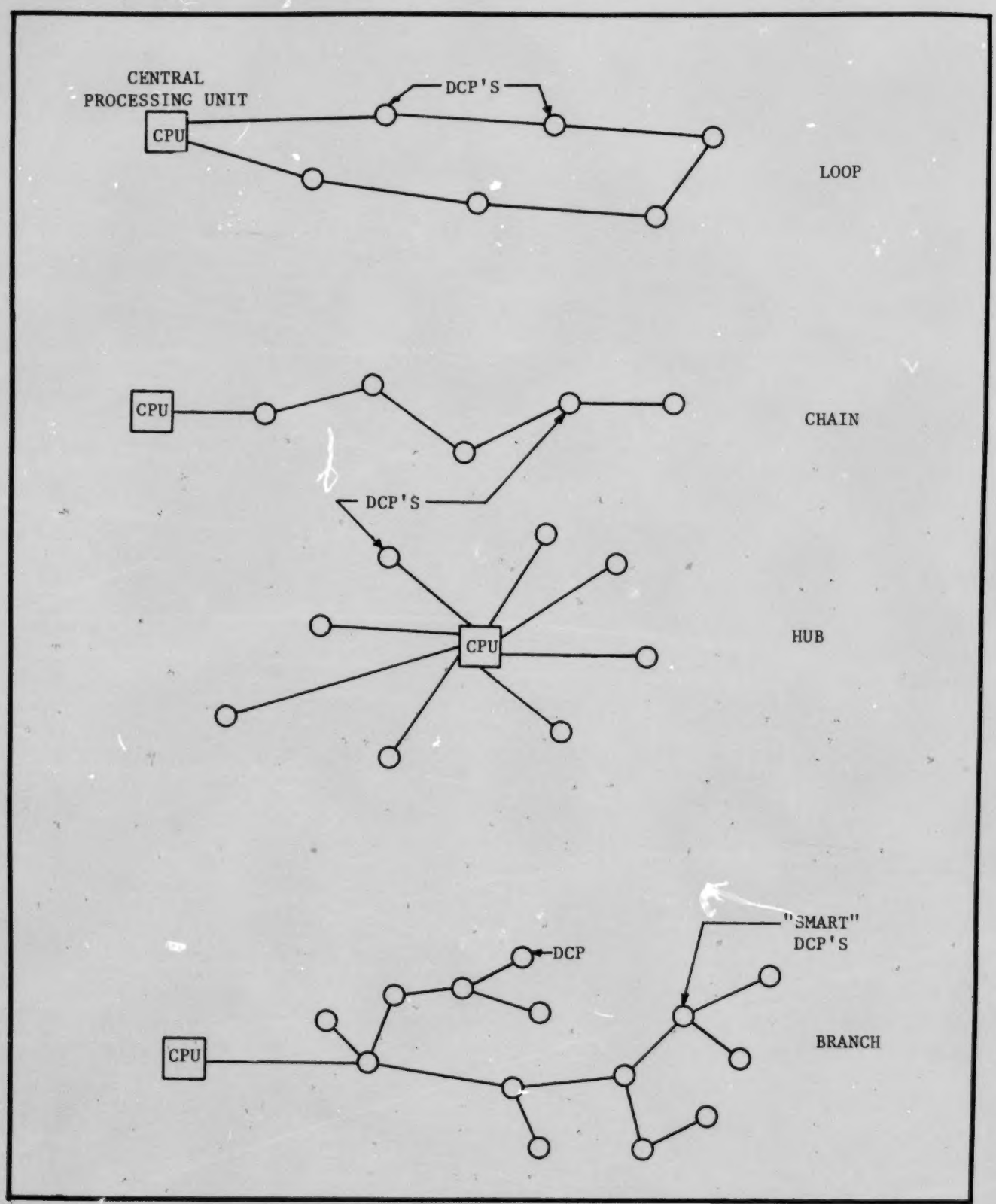

Fig. 3 -- Data transmission link configurations

to as the "baud rate." Generally, they are full-time lines continuously connecting the automation system components of widely separated but related sites where the running of proprietary cables is impractical. It is generally recommended that leased lines be four-wire, full-duplex. This is especially true where multiple buildings connect radially to the CPU.

4. Voice-grade circuits are low-speed direct-current lines capable of handling binary data at speeds up to 9,600 bits per second. Generally, however, they are utilized at 1,200 bits per second, since no special conditioning of the circuits is needed for operation at this speed. The 1,200-baud rate design is primarily an economic consideration involving cost of leased lines versus data-response requirements. Circuit length is unlimited. All building automation functions can be implemented via voice-grade circuits.

5. Utilities providing leased transmission lines require the customer to carefully limit the power of his signals and their frequencies. To facilitate this, standard interface units called modems or data sets can also be leased from the utility or purchased from the CCMS manufacturer.

6. Signal characteristics differ among manufacturers of automation systems, and special cables that provide transmission links have been chosen particularly to match. The trend among manufacturers is toward the two-wire serially transmitted data system. This is because of rising costs of wire, labor to install it and advancing technology that permits transmission of large amounts of data over a simple circuit.

7. Information in digitally coded serial form is in the form used by today's low-cost digital processors and computer systems. Digital transmission makes possible data accuracy checks and low-cost leased-line operation.

Flexibility

General Considerations

The master plan (described in Chapter IV) will establish the approximate system size in regard to the number of points. This point count and the description of the point type, i.e., binary, analog, start/stop, etc., will determine the size of the CCMS with regard to memory. It is important to also establish, at the outset, the project total point count including the recommended 10 to 20 percent (preferably 20 percent) cushion.

The ultimate number of points should be used in establishing the size of the CPU and the capacity of the DCPs. The impact of the CPU selected for the required point count of the initial phase of a multiphase project is not as severe today as it was previously. Most manufacturers have designed the CPU hardware to permit "plug-in" additions of memory with little or no penalty for future additions. The DCPs are another matter, however. DCPs are manufactured in several sizes. If an ultimate point count and type of anticipated points are not established, then the DCPs may not be large enough to handle future requirements. Replacing or paralleling DCPs may run into thousands of dollars for each remote data-gathering location.

Most computer-based CCMSs utilize well-known off-the-shelf minicomputers. For example, Johnson Service uses a Modcomp II, modified; Powers uses a Data General Corporation Nova; Robertshaw, Computer Automation Model L81/2-20; and CompuGuard, Digital Equipment Corporation PDP-11. Honeywell's Delta 1000 utilizes a microcomputer in its CPU with microprocessors in the CRT terminal and printer. The equipment noted here is readily expandable to accommodate reasonable additions of points.

One aspect of making changes that does involve time and expense is those changes requiring program modifications. These are required when the point address list is expanded or altered. A paper tape of the affected program must be generated at the factory with charges of approximately $250 plus $2 per point.

CPU Memory Changes Made from Keyboard, not Requiring a New Tape

1. Analog limits/differential settings--allows operator to set individual high and low limits with differentials for each analog input.
2. Time programming--allows individual seven-day programs to be set for commands. Each command point will have its own seven-day program.
3. Time-day-date entry--allows on-line entry of the time, day of week and date from keyboard device.
4. Password delete/change--a person can be assigned a password that will allow access to only those functions and points necessary to do his or her job. Access to the password-enter function is normally restricted to supervisory personnel.
5. Trend log entry--the operator can assign any 12 points to the trend log function. He or she can also enter the trend log-time (0-99 minutes) in one-minute intervals.
6. Run time totals entry--the operator can enter a high limit and reset/preset the totalized run time value for each run time point. The system will totalize run time for each point and output an alarm message when the limit is exceeded.
7. Analog totals entry--the operator can reset/present the totalized value at any time. The system will totalize the analog value of each point with time.
8. Btu totals entry--the operator can reset/present the Btu totals for all points assigned to this function during system design. The system will totalize Btus for each point.

Software Programs

Software program input is made through magnetic tapes, paper tapes or cards containing the basic operating instructions for the computer. Software input is stored in the computer in core memory or in bulk storage. Generally, the CCMS equipment manufactured today is computer-based and utilizes software. The Honeywell Delta 2000 requires the addition of a computer, a Honeywell 316, in order to utilize software input for optimization programs.

Typical software programs include:

- executive program and operating instructions
- start/stop*
- load-rotation (duty cycling)*
- load-shedding (with demand limiting)*
- reset*
- alarms
- optimization*
  --optimum start
  --outdoor air (enthalpy)
  --supply air reset
  --chiller plant
- power factor improvement*
- load and performance profiles*
- maintenance management*
- lighting control*
- fire alarm/security program
- watch tour

*See also Chapter XI, Adapting Central Control and Monitoring Systems to Energy Management, for additional information on energy conservation software programs.

Executive Program and Operating Instructions

These programs are essential for the function of the computer itself as they keep track of real time, control the priority of signal processing, direct information in and out of memory, control the operation of all associated hardware and encode/decode incoming and outgoing signals. An essential part of these programs is the orderly shutdown of the computer in the event of power failure to ensure that all information is safely stored in permanent memory before power is lost.

The operating instruction programs that include the real time program, procedures for handling I/O functions, data base storage and change of state program are included in the fixed software.

Self-diagnostic programs are generally

incorporated within the basic format of computer-based systems. These programs continuously scan the entire system for faults. Upon detection of a failure of a sensor or point-module card, an alarm is initiated together with information relative to the nature of the failure and, in some cases, the location of the DCP and the point-module card that contains the failure.

Start/Stop Program

This is the simplest type of program; yet, with modifications, it becomes the most effective energy saver, particularly when used in conjunction with other programs and routines.

In its simplest form, a start/stop program is arranged to start and stop equipment according to a predetermined schedule. The program can also open and close dampers, turn lights on and off, and reset temperatures for occupied and unoccupied situations.

In this program, manual override can be provided with automatic reversion to program control at the end of an occupied or unoccupied period.

Load-Rotation Program

This program may be a part of a load-shedding program or may be an independent software package, depending upon the manufacturer's format. One manufacturer refers to it as "duty cycling." Under this program, the CCMS cycles selected electrical loads on and off during the day to reduce energy consumption.

Load-Shedding Program

This program is used in conjunction with the start/stop program to override normal operation and to turn off equipment as a predetermined peak load value is approached. In its simplest form, the program would shut down selected equipment according to the measurement of peak load. The program can be modified to include a rolling priority feature. This feature allows equipment to be shut down on an assigned priority basis for a predetermined period of time after which it is returned to service and a lower priority piece of equipment turned off. The rolling priority would only be activated when a predetermined peak load value is approached, and the equipment turned off would be limited to that necessary to make certain that the load remains below a given level.

Reset Programs

These programs are designed to reset the control points of thermostats and pressure controllers, and to interface with load shedding and optimizing programs. In place of, or in addition to, turning off equipment for load shedding and energy conservation, loads can be trimmed, i.e., if a peak load is being approached, space conditions can be reset to reduce cooling or heating loads; outdoor air dampers can also be reset in this type of program. (See also the supply air reset optimization program described under Optimization Programs, below.)

Alarm Programs

These programs report alarms generated either outside the computer (fire alarm pull boxes, boiler high pressure, etc.) or in computer software. Upper and lower limits can be set in software for any monitored point. An alarm will go off when these limits are reached.

Alarm programs can also be interfaced with the start/stop program to monitor hours of equipment run and report a maintenance alarm when a designated number of running hours is reached. Information on particular maintenance required can be stored in memory and be printed out when the alarm is reported. (See also Maintenance Management, below.)

Optimization Programs

These programs tend to be more sophisticated than the others described so far, requiring interface with an arithmetic routine to allow optimum settings to be calculated. The optimizing program interfaces with the start/stop program, load-shedding program and reset program to modify operation of equipment. Most of the following programs are available from the major CCMS manufacturers. Some of the programs are available only from certain companies or must be written specifically for the project in question.

1. Optimum start: This program can delay the start of primary equipment, such as chillers, boilers and individual air-handling units, until the last possible moment to provide a comfortable environment in the space at the time of occupancy.

2. Outdoor air (enthalpy): This program utilizes outdoor air for "free" cooling. All outside air will be used when outside air enthalpy is between that of the return air and the required cooling-coil-leaving air condition. When outdoor air is colder, it will be mixed with return air to suit desired supply air enthalpy.

3. Supply air reset: On fixed-volume reheat systems such as all-air-terminal reheat systems and on double-duct systems, the supply air temperature for cooling is usually fixed. Decreased cooling loads on the system are reflected by increased reheat (steam or water coils or air from the hot deck) with no change in the supply air temperature. For terminal reheat systems, the supply air reset program receives an input indication of the reduced cooling load. Supply air temperature is then raised according to the amount of cooling load reduction. This reduces the amount of mechanical cooling used and the amount of reheat required at the space. Supply air temperatures are only raised within the limits of the humidity requirements as established by the comfort chart and as controlled by return air controller override.

4. Chiller plant: The chiller plant optimization program applies to series or parallel-piped, absorption or centrifugal chillers. The program assumes that each chiller is provided with a means of reducing its capacity (inlet vanes, variable steam supply, etc.) and that a curve can be provided that approximates the I/O characteristics. Multiple-cell cooling towers, with fans that can be started and stopped or varied from high to low speed, are also included. The program is based on centrifugal chillers; however, absorption chillers can be handled in the same manner, although the inputs may be sensed differently.

Power Factor Improvement

This program provides continuous monitoring of the power factor for individual buildings on the entire complex, as appropriate. When the power factor drops below a reset limit, the system automatically switches in a bank of capacitors to provide power factor correction. If the power factor is still below the desired value, the system will automatically pull in the second and succeeding banks until the desired correction is achieved.

Load and Performance Profiles

This program is not a standard software package but is useful for building management, cost-reduction analysis and long-range strategy planning. The most common variables that are integrated include daily and monthly cooling and heating loads, daily and monthly kilowatt-hours (kwh) demand, kilowatt (kw) demand, and total electricity, gas, oil, steam or other prime energy costs.

Maintenance Management

Maintenance programs are "canned" or written specially for a particular project. They are intended to put maintenance on an efficient basis concerning primarily preventive maintenance as opposed to emergency procedures. The programs typically consist of the following elements:

- building inventory
- equipment inventory
- maintenance task information
- maintenance schedule
- work order generation
- maintenance cost information

Lighting Control

This program can be effective in reducing lighting kwh providing it is utilized in new construction or remodeling programs. This program can ensure that lights are on only when actually required. Lighting schedules may be established for

the entire building or portions of the buildings as may be required for departmental work-hour variations. Computer program override is available through the keyboard to accommodate unscheduled overtime hours.

Fire/Security Alarm Programs

These programs are offered by each manufacturer and are tailored to the particular building or buildings in question. Fire alarm programs are designed to be compatible with the class of system being contemplated. Most CCMS systems comply with National Fire Protection Association (NFPA) Standard 72D. The "class" of system, A, B or E, is determined by the code and/or special requirements. It determines the complexity and cost of the system. Security alarm programs offer a myriad of options but basically monitor two position contacts and alarm upon occurrence of an unscheduled "event." Prerecorded audible messages or typewriter instructions usually are provided and are to be activated by fire/security alarms.

Watch Tour Program

The watch tour program provides benefits by automatically monitoring the tour of a guard. When a guard reports at a watch tour station, the system logs the report, including date, time and location. The system also monitors:

- failure to report at a station within a specified time limit
- whether stations are accessed out of normal sequence
- arrival at last station prior to specified early-end time

Recommendations

Certain software programs are required to make the system operate. The executive program and operating instructions are fundamental to the computer-based system. The most efficacious program is start/stop with variations. Variations of the basic program are load-rotation, load-shedding and optimum start. This program must be flexible in regard to number of controlled devices (motors especially) and the on/off schedule. Modifications to the program should be field programmable to meet the changing needs of the institution.

The optimization packages must each be analyzed to determine the pay-back period for each software package investment. Software costs vary from a few thousand dollars to more than $20,000 for maintenance management.

CHAPTER IV

PLANNING AND ECONOMIC ANALYSES FOR CENTRAL CONTROL AND MONITORING SYSTEMS

PLANNING
- Feasibility Survey
- Goals
- Engineering Feasibility
- Estimate of Benefits
- Costs Associated with Central Control

COST JUSTIFICATION: ECONOMIC ANALYSIS
- General Concepts
- Investment Data
- Classes of Economic Analyses
- Primary Versus Secondary Economic Analysis

ANALYTIC TECHNIQUES USED IN ECONOMIC ANALYSIS
- Pay-back Method
- Present Value Analysis
- Net Present Value (NPV)

CHAPTER IV

PLANNING AND ECONOMIC ANALYSIS FOR CENTRAL CONTROL AND MONITORING SYSTEMS

Planning

Before undertaking a Central Control and Monitoring System (CCMS) program, someone must be assigned to head the project. Two positions or tasks must be addressed and accommodated. The first is a key administrative position, preferably filled at the level of assistant director of physical plant. The assistant director must be knowledgeable in mechanical and/or electrical engineering and have an understanding of building mechanical and electrical systems. This person would provide a high-level interface between the project and the institution's management. Policy decisions would be made by or through the assistant director.

The second position, which requires staffing before starting project design, is a full-time design engineer. The design engineer may be the project engineer assigned to the project by a consulting engineering firm engaged by the state or directly by the institution, or the design engineer may be hired by the institution staff to exclusively handle the CCMS project.

There are advantages and disadvantages with either approach. The in-house engineer would probably represent a smaller financial outlay, at least at the outset. Also, being on the staff (and payroll) he may be better attuned to existing needs because of his proximity to the problem.

The consulting engineer offers broad-based experience, which assures objectivity in the design. Further, he is intent on providing good service to his client because he is in the service business and the continued success of his business is dependent upon satisfied clients.

Once the design team is settled upon, the planning process begins. If not already available, a building inventory must be prepared. The inventory should list, as a minimum, the following data:

- building number and name
- gross floor area
- year constructed
- function(s)
- number of "points" to be controlled
  --environmental
  --fire alarm
  --security
- estimated equipment cost
- estimated total cost

All buildings should be listed on the inventory chart. However, this does not mean that all buildings will be served by the CCMS. That determination is made later by the team and is dependent primarily on life-cycle cost analyses. Small buildings, temporary buildings, older buildings to be razed and buildings that are not energy-intensive are early drop-outs from the CCMS list of candidate buildings.

As the process evolves, additional building data are accumulated and include number, type and size of heating systems, air systems, ventilation load, refrigeration requirements, electrical data including usage and demand, and type and hours of occupancy. These data are then used to calculate per square foot information, which is useful in establishing priorities for retrofit and in making the life-cycle cost analyses.

The master plan that evolves should contemplate a 10-year period. Each proposed building addition or foreseeable academic need that can be translated into building requirements must be accounted for in the master plan. A contingency factor of 10 to 20 percent should be included in the accounting of requirements to cover unforeseen needs.

An economic analysis to justify CCMS program expenditures is included in Appendix A.

Feasibility Survey

The first step in procuring a CCMS should be a feasibility survey and study. This study is to determine the economics related to capital investment and the engineering feasibility of performing alarm, signal and control functions effectively. Small CCMSs (that is, systems with less than 100 points) can be purchased without a thorough economic analysis and as a "shelf item" from a manufacturer.

As the systems increase in size, the cost and benefits of alternate systems must be considered. Before starting to plan for a CCMS, someone must determine the scope of the system under consideration. A survey of the facility should be performed, with engineering and economic feasibility studies to include:

- meetings with the owner to determine the goals of the system
- survey, study and investigation to determine engineering feasibility
- conceptual system design
- estimate of savings produced by conceptual designs
- estimate of first cost (or alternate cost)
- economic analysis for savings investment ratios (SIR), cost benefit factors (CBF), pay-out schedules and life-cycle costing

Goals

Management goals should be established early. These might include:

- reduction in manpower costs
- improvement of occupant services
- reduction of energy costs
- safer building conditions
- improved maintenance
- reduction in vandalism
- better control of operation budgets
- improved management reports
- occupant complaint verification
- improved critical area surveillance
- step-by-step capital funding

Engineering Feasibility

To determine engineering feasibility, arrange the goals in a hierarchy, with the participation of management. Examine feasible engineering solutions to meet all steps of the hierarchy, then perform a physical inventory of the existing facility to determine all factors affecting the goals. A theoretical device list should be prepared for new facilities.

Estimate of Benefits

Make dollar estimates of savings for items that can be quantified and determine the total dollar savings for the system. Then, prepare conceptual line diagrams of the system, listing the various components required to produce the estimated savings and the associated construction costs.

Costs Associated with a CCMS

Evaluation of a CCMS requires consideration of initial costs and recurring costs in each area affecting the CCMS. These areas would include:

- survey and study preparation costs
- planning and engineering costs
- management costs
- CCMS initial costs
- initial costs related to existing system modifications
- training costs
- operating costs, including a reduction in electric power, fuel and labor, and possibly an increase in labor costs in other areas
- maintenance costs in-house
- maintenance contracts

Cost Justifications: Economic Analysis

Rigorous analysis techniques should be used to determine the savings investment ratios (SIR) and other life-cycle cost factors relating to the CCMS. Consideration should be given to the expected life of the system; the current and future cost of money; and the escalated inflation rates of electric power, fuel oil and labor. These data determine the economic viability of alternate solutions. These solutions should then be presented to management so a decision can be made.

General Concepts

Economic analysis techniques have gained increasingly widespread support in recent years. Economic analysis procedures

enable physical plant administrators to present available investment proposals to decision makers to be ranked in some order of attractiveness for inclusion in the capital budget.

The essence of an economic analysis is the comparison of investment costs with the benefits that are expected to result or the comparison of costs and benefits of various investment alternatives. The investment and the resulting benefits are measured in dollars. Most analyses are complex, involving the comparison of several proposals and the expenditure of both present and future resources.

Investment Data

Before any analysis of a proposed investment can proceed, a certain amount of data must be generated and arranged in a logical pattern. The estimated costs of the proposal, including one-time investment costs, annual costs and net increases in working capital, form the project cash outflows. Cash inflows may consist of sale of assets or residual values attributable to the project.

Classes of Economic Analyses

Economic analyses may be classified as either primary or secondary. A primary economic analysis is one employed to help determine if an existing situation or procedure should be changed in some way to take advantage of dollar savings available through some other situation or set of procedures. This analysis would discuss the basic need for some change to present conditions.

Some examples of primary economic analyses are:

- expansion of utility systems to eliminate individual boiler plants
- modernization of overhaul facilities to speed overhaul work, thereby decreasing the "pipeline" inventory requirements
- connection to municipal utility systems in lieu of continuing to operate owned utility systems
- replace existing high maintenance cost facilities or equipment with new facilities of similar capacity

A secondary economic analysis is one that is used once a deficiency or changed requirement has been identified to determine which of two or more alternatives would most economically satisfy the deficiency. This type of analysis does not concern itself with the basic need for the construction project but with the choice of alternative ways to satisfy a previously stated basic need or deficiency. Examples of such alternatives are:

- meet an increased base utility requirement by enlarging the present plant versus connection to a commercial source
- correct existing deficiencies through new construction versus rehabilitation of existing facilities
- provide new construction by one of several different design concepts or by use of one of several different types of construction materials

Primary Versus Secondary Economic Analysis

Additional discussion of the basic differences between primary and secondary economic analyses is necessary to assure that budget submissions reflect those differences. Primary economic analyses are those which involve proposed savings over an existing mode of operation. Investments justified on the basis of a primary economic analysis must promise absolute cost savings over the present method of accomplishing a task.

Secondary economic analysis, on the other hand, refers to a method of selecting the most economic alternative from a group of alternatives all designed to perform a function or satisfy a mission that is not justified on the basis of dollar savings.

Analytic Techniques Used In Economic Analyses

Through the years, a number of methods for analyzing the costs and benefits for investment decision making have been developed. They range in complexity from the simple pay-back analysis to the more sophisticated discounted cash flow methods.

Two techniques of analysis will be discussed in this section: pay-back period and present value (PV). Another method, savings investment ratio (SIR), exists, but it is not discussed in this chapter.

Pay-back Method

The pay-back method is a simple expression of the period of time estimated to recover the investment cost of the project through the incremental cash flows attributable to the project. More specifically, the pay-back period is a way of stating the number of years by which future savings will match the added investment cost.

The critical shortcoming of the pay-back method is its failure to consider cash flows after the period of recovery of and above the dollar values of the investment. For this reason, it is not a measure of the profitability of a potential investment and should seldom be used to choose between several projects.

It is, however, sometimes desirable to express the results of an economic analysis in terms of the "pay-back period," particularly if addressing persons not familiar with economic analysis terminology.

Present Value Analysis

Since both benefits and costs usually accrue at varying points in time, the most meaningful comparison between the two can be made when each is summed to a common point in time. The present point in time is normally selected for cost/benefit comparison. This relationship between the value of payments received at different dates is of fundamental importance to the present value and the SIR methods of economic analysis.

If $100 is left on deposit for five years at 6 percent interest, to what amount will it have grown at the end of that period? Returning to the general case, the future value F_1 at the end of year one can be reinvested at the same interest rate. Thus,

$$F_2 = F_1 (1 + i) = P (1 + i) (1 + i)$$
$$F_2 = P (1 + i)^2$$
$$F_2 = 100 (1.06)^2$$

where F_2 is the future worth of the amount F_1 after one year, or the future worth of P after two years.

Similarly, F_3, the balance after three year, is found as

$$F_3 = F_2 (1 + i) = P (1 + i)^2 (1 + i)$$
$$F_3 = P (1 + i)^3$$

In general F_n, the future (or "compound") amount at the end of the year n, is found to be

$$F_n = P (1 + i)^n \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Thus, with an interest rate of 6 percent, the future value of $100 at the end of five years if

$$F_5 = \$100 (1.06)^5 = \$100 (1.34) = \$134.$$

The present value of future money, received or saved annually for succeeding years, can be computed as follows: The computation of the present value of $1 to be received annually for a period of three consecutive years can be calculated using Table A.

End of Year	Dollars Received	Present Value Factor (Table A)	Present Value of this Year's Cash Flow
1	$ 1	0.954	$ 0.95
2	1	0.867	0.87
3	1	0.768	0.79
Sum of present value of annual cash flows		=	$ 2.61

Alternatively, we can use Table B to make the same calculation. Table B contains factors used to calculate the present value of a single dollar flowing annually for n years where n goes from one to 25 years discounting at an annual interest rate equal to 10 percent. Thus the present value (P) of a series of three $1 cash flows occurring at the end of years one to three may be calculated as:

P = VR

where: V = Present Value Factor for an annual series of cash flows for n years discounted at 10 percent

R = the value of the constant annual cash flow, and the present value factor is taken from Table B

P = ($1) (2.61)

P = $2.61

Net Present Value (NPV)

To implement the present value approach, simply find the present value of the expected net cash flow of an investment discounted at the appropriate interest rate (10 percent for most investments) and subtract from it the initial cost outlay of the project. If the net present value is positive, the project should be accepted; if negative, it should be rejected. If two projects are mutually exclusive, the one with the higher net present value should be chosen.

Costs to be itemized include:

- operating costs other than labor: Each major subcategory for which costs will be significant should be itemized.
- overhead: These may be costs for accounting; legal work; local procurement; medical services; and receipt, storage and issue of supplies, police, fire and other services.
- adjustments for inflationary trends: When there is a reason to believe that prices will significantly affect the choice between alternative investment proposals, the analysis should use the best available data-projecting material and labor increases.

PROJECT YEAR DISCOUNT FACTORS

TABLE A

Present Value of $1
(Single Amount--to be used when cash flows accrue in different amounts each year)

Project Year	10%	Project Year	10%
1	0.954	13	0.304
2	0.867	14	0.276
3	0.788	15	0.251
4	0.717	16	0.228
5	0.652	17	0.208
6	0.592	18	0.189
7	0.538	19	0.172
8	0.489	20	0.156
9	0.445	21	0.142
10	0.405	22	0.129
11	0.368	23	0.117
12	0.334	24	0.107
		25	0.097

TABLE B

Present Value of $1
(Cumulative Uniform Series--to be used when cash flows accrue in the same amount each year)

Project Year	10%	Project Year	10%
1	0.954	13	7.453
2	1.821	14	7.729
3	2.609	15	7.980
4	3.326	16	8.209
5	3.977	17	8.416
6	4.570	18	8.605
7	5.108	19	8.777
8	5.597	20	8.933
9	6.042	21	9.074
10	6.447	22	9.203
11	6.815	23	9.320
12	7,149	24	9.427
		25	9.524

Note: Table A factors represent an arithmetic average of beginning and end-of-the-year single amount factors found in standard present value tables. Table B factors represent the cumulative sum of the factors contained in Table A through any given project year.

CHAPTER V

EQUIPMENT SELECTION FOR INITIAL PURCHASES AND EXPANDING SYSTEMS

STATE OF THE ART

SYSTEM RELATIONSHIPS

INITIAL PURCHASE CONSIDERATIONS
- Peripheral Priorities
- Flexibility for Future Expansions

EXPANDING AND INTERFACING SYSTEMS
- Expanding
  - Planning
  - Implementation
- Interfacing
  - Apples and Oranges?
  - New Tangerine with an Old Orange?

CHAPTER V

EQUIPMENT SELECTION FOR INITIAL PURCHASES AND EXPANDING SYSTEMS

State of the Art

Computer-based Central Control and Monitoring Systems (CCMSs) were introduced on an experimental basis in the mid-1960s and as catalogue products in the early 1970s. The growth of this segment of the control industry and the rate of change of hardware are directly related to the events occurring in the computer industry itself.

When Honeywell introduced its Delta 2000 line, many people thought that the sales term "computer-oriented" implied some sort of computer within the system architecture. After reading the fine print, or perhaps after purchasing a system, they learned that the plain Delta 2000 contained hard logic, not software-based logic. To achieve computer capability, an add-on 316 computer must be purchased to upgrade the system to a Delta 2500 level. The Delta 2000 system, with or without the add-on computer, has been a "best seller," with well over 1,000 systems installed.

Other manufacturers countered the Honeywell strategy with real computer-based systems. Johnson Controls came out with its JC-80 in two forms, a "stand alone" for small projects and a sun-satellite arrangement for larger projects. Powers also offered a computer-based system known as a 570 with an English language CRT and keyboard as its contribution to the state of the art. The other manufacturers generally followed the computer-based system approach. Whatever the configuration, systems required a period of adjustment for the manufacturers to debug the hardware and software.

It appeared that the major manufacturers had at last settled on their system format and had enough projects under construction to work out the inherent defects. The potential customers who had not yet purchased a system could be assured of workable systems utilizing proven hardware and technology.

This happy situation did not last long, however. The computer industry is undergoing a revolution that has reverberations into the CCMS field. Hordes of microprocessors are invading the control industry and competing head-to-head with minicomputers for control responsibilities.

Just when the industry had settled on proven hardware, the computer industry had a shake-up that has started the update race again. Honeywell leapfrogged the industry with their microbased Delta 1000, which is cheaper and perhaps better than the venerable Delta 2000. Powers had introduced a decentralized system utilizing "smart" DCPs and microchip sensors.

Where do these changes or "improvements" place the prospective customer or the recent purchaser? Hopefully, the changes are truly improvements and not merely offerings to obtain or maintain a marketing advantage.

System Relationships

It may be reassuring to know that the role of the central station hardware, at least monetarily, is only the "tip of the iceberg," representing typically 10 to 20 percent of the total investment.

This may not be good news, however, for the uninitiated. When one considers the size of the investment for the "tip," what can the entire iceberg be worth? The following diagrams illustrate the relationship of the cost of the components of two systems. The first (Fig. 4) is a project at Ft. Meade, Maryland. This project is unique in that all 120 buildings are to be connected by government-furnished telephone lines to the CPU. This fact is the main reason for a low per building cost factor.

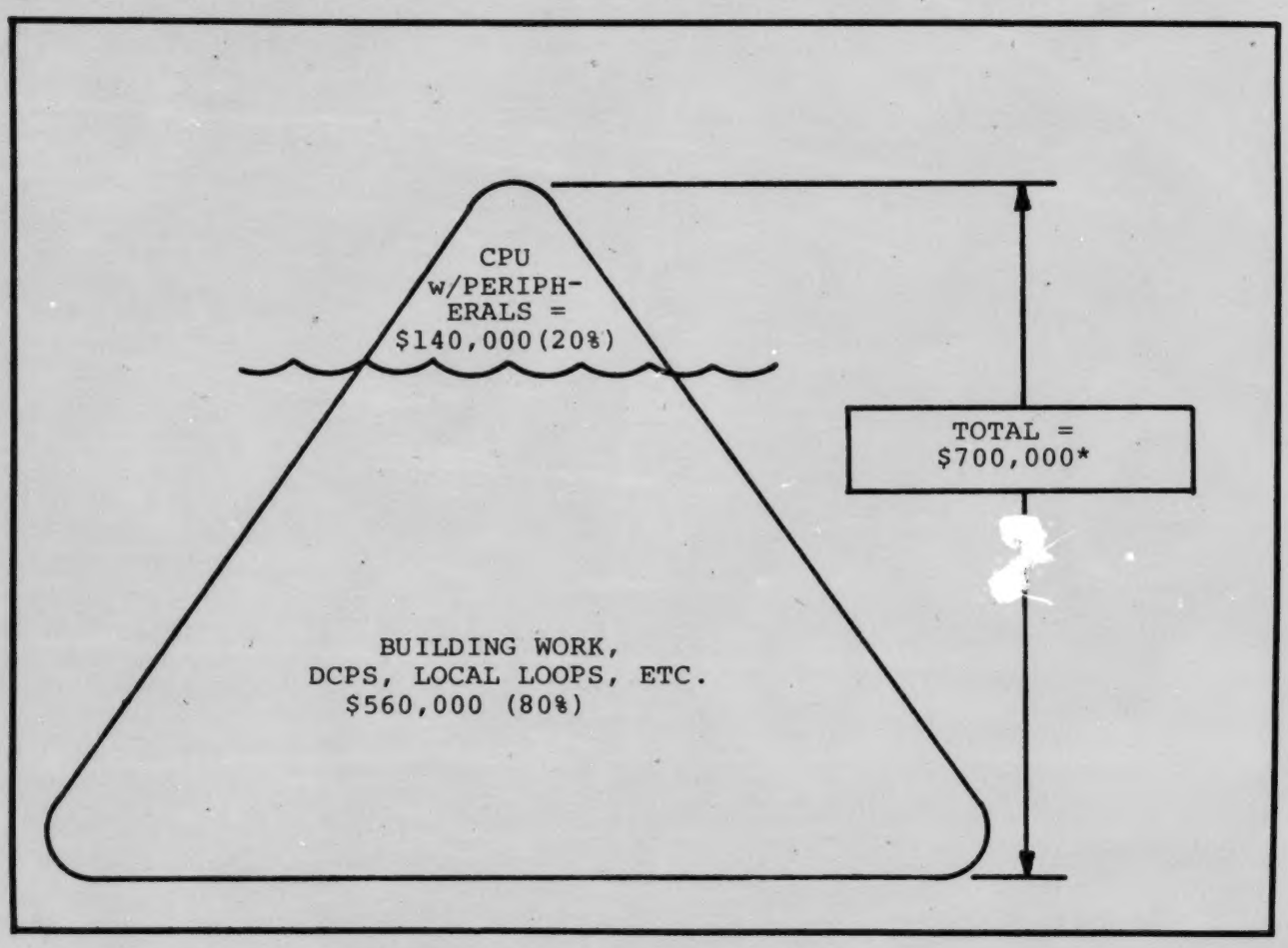

Fig. 4--System cost distribution
CCMS, Ft. Meade, Maryland

*Does not include government-furnished data transmission system.

The University of Maryland project (Fig. 5) in the design phase was to include 108 energy-intensive buildings. Unlike Ft. Meade, most of the buildings contain sophisticated mechanical systems and numerous life safety points.

Initial Purchase Considerations

It is intuitive from examination of the "iceberg" diagrams (Figs. 4 and 5) that the central station or command center hardware is a relatively small percentage of the overall project cost. This relationship suggests that wise investment in this part of the system is of the utmost importance. This "heart" or "engine" of the system establishes the real capability of the complete system. The opportunity exists when selecting the CPU and peripherals for the command center to provide the basis of a powerful, vital and flexible system. The decision on how to spend that 10 to 20 percent of the total system cost determines whether the total system has a chance of success or is destined to mediocre performance from the outset. It is essential, therefore, not to buy short on this end of the system.

Irrespective of the procurement method employed, the CPU should be selected with built-in capacity and features for the entire project, including a 20 percent cushion for future expansion. If funding is extremely tight, then the initial purchase could be a first increment of a modular, expandable chassis. Certain manufacturers have three series of central station equipment, somewhat like the mail-order house

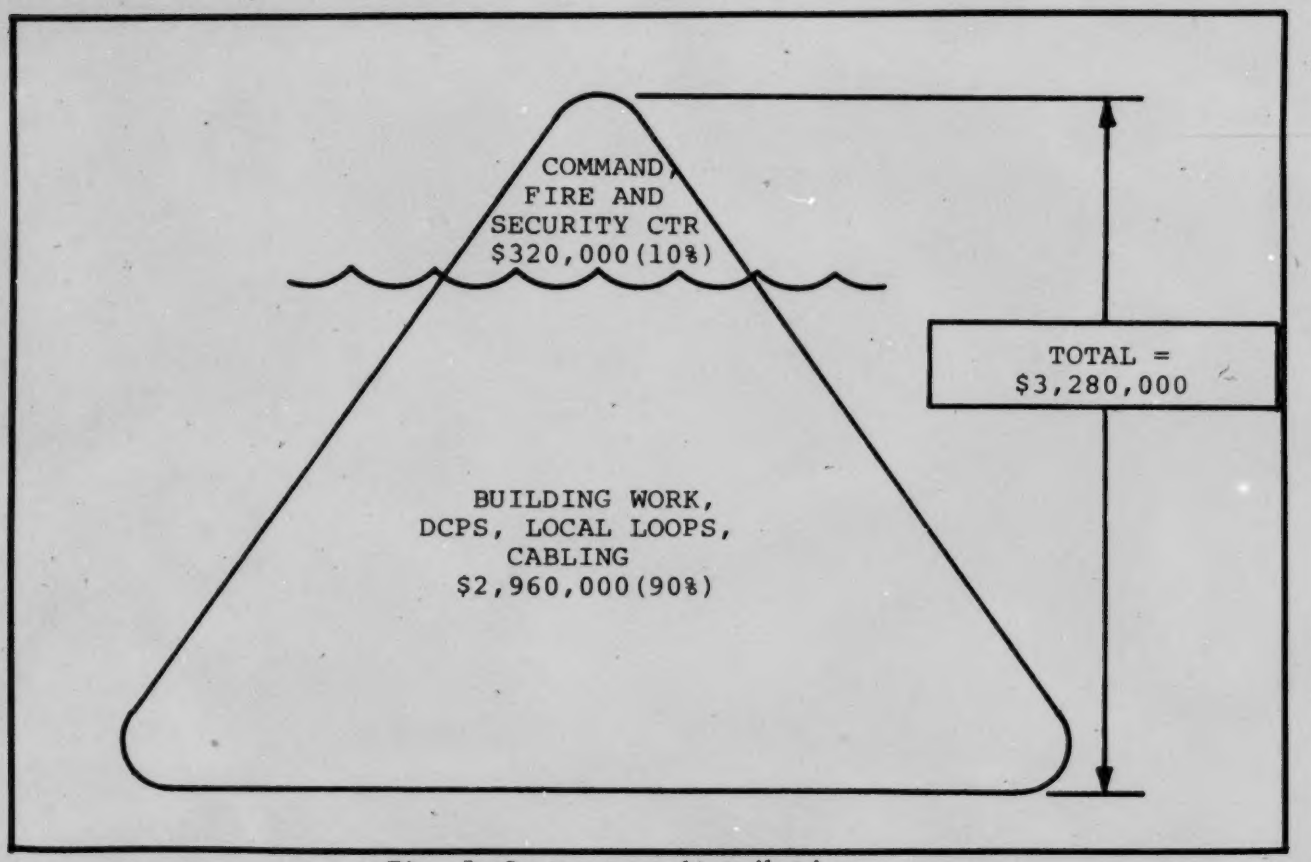

Fig. 5--System cost distribution
CCMS, University of Maryland

"good, better and best" format. Beware of bottom-of-the-line equipment. It is neither adequate nor expandable, although certain manufacturers offer up to 50 percent trade-in allowance on the purchase of a higher level system.

A reasonable central station starter set should include a real-time minicomputer (or micro equivalent) with 32K memory, expandable to 64K, and compatibility with disc for future flexibility; a CRT with key pad; a teletypewriter; a high-speed line printer with alarm messages printed in red; and a graphic module sized for two 80-slide projectors. The CRT key pad should have function keys for common addresses such as start, stop, alarm acknowledge, alarm summary, trend log, all-point summary, reset, increase, decrease, graphics on/off and execute. A back-up power supply should, of course, be included with any starter set. The loss of the computer due to loss of power or a computer malfunction usually cannot be tolerated. Some starter sets include back-up power in the form of batteries. A four-hour supply is recommended where there is an emergency generator system available for long-term supply. Where there is no emergency generator, a 24-hour battery system should be provided.

Software programs that should be part of the initial purchase would include:

- executives with diagnostics
- start/stop
- alarm
- load-rotation
- load-shedding (with demand limiting)
- optimized start
- reset (including supply air)

Peripheral Priorities

The consequences of a computer malfunction can be avoided by providing a back-up computer, either a copy of the main or some less expensive version with

reduced capabilities. This back-up capability should be a first choice in selection of optional equipment.

Intercom is another peripheral that is almost a must. It is possible to use the building telephone system but direct communication at each DCP with the central station is highly desirable, not only for maintenance instructions but for motor-start verification.

Additional printers are an early choice for add-on purchases. Printers dedicated to firm alarm, maintenance, load shed, security station and night-time duty office should be considered. Wide-carriage, high-speed printers may not be required at all locations. Slower-speed typewriters or narrow-width strip chart printers may well serve the purpose for these auxiliary requirements.

Annunciator panels for fire and security systems are desirable features for remote locations in the absence of a CRT. The panels are designed for audible and visual alarming of the specific points served by the subsystem in question. The annunciator would operate in conjunction with a typewriter printer dedicated to specific functions.

Flexibility for Future Expansions

There are basically two elements that affect the flexibility of the CCMS. These elements are the CPU and the data collection panels (DCPs). The CPU should be an adequately sized computer-based unit. The memory should be 32K minimum with plug-in modular expansion capability to 64K. CPU design should also permit use of disc storage for optimization programming. Equipment selected should be of a well-known manufacturer to assure future procurement of parts, programs and service.

DCPs should be sized to handle present points plus 20 to 50 percent additional capacity for future additions or changes. Manufacturers make DCPs in several sizes with certain fixed point or card capacity. There is little extra expense for selecting a DCP with spare capacity. It is another story, however, should the DCP be filled when more points are added to the system.

Expanding and Interfacing Systems

Expanding

Planning

When adding points to an existing CCMS, problems may arise due to unsuitability of existing equipment with regard to expansion. Adding points to an existing system may entail the purchase of another computer, the purchase of additional memory, the purchase of more and larger DCPs, reprogramming inconvenience, inflated factory charges and disruption of the normal operational routines. These problems can be avoided or at least minimized by looking ahead at the time of the original investment. This is usually handled in two ways. If a long-range campus plan exists, both existing and proposed buildings can be identified and points allocated at the outset. If no reliable long-range plan is available, then an allowance for future growth should be made.

These provisions for future growth affect several parts of the CCMS, some more drastically than others. Perhaps the most critical item in the CCMS hardware format is the CPU with its memory and software programs. It is important to make certain that equipment purchased either has the spare capacity for all future growth or that it has a modular format that permits the easy addition of more points in the future. The wiser course of action is to include excess capacity at the outset. Be wary of systems that are at their limit at the outset of the project. Avoid getting stuck with the "Contractor's Special."

Between the CPU and the sensors, the field wiring and the DCPs can be designed to reduce the impact of future expansion. The present state of the art requires either a coaxial cable or twisted pair between DCPs. No additional wiring should be required if all DCPs were purchased initially. Problems may arise if the DCP has not been specified and/or furnished with adequate spare capacity. DCPs vary in cost from $2,000 to more than $5,000, with a good assortment of point-module cards. Replacing a DCP or adding a new one can be expensive and inconvenient. It is suggested that DCPs be selected to handle all known future points plus 20 percent expansion capacity.

Any known future buildings, air-handling units or other equipment can have space reserved on the CRT format and then have information field programmed when adding those anticipated points. If major unplanned changes or additions are made, a paper tape must be generated and sent to the factory for revisions. There is a charge for factory reprogramming that can range from hundreds to thousands of dollars, depending upon the manufacturer's policies and the nature of the hardware. Certain manufacturers claim their systems are field reprogrammable which, if true, would permit less expensive manipulations of the software.

Another method which should protect the owner was suggested in the first section of this chapter. This method involves receiving unit prices on items for future expansion at the time of the original bid. With an agreed-upon cost index or escalation factor, all future additions should be easily priced using the unit prices given for DCPs, point cards, cable and connectors.

Implementation

Circumstances may preclude the use of unit pricing or other mutually acceptable methods for contractor-installed additions. This may precipitate a decision on the part of the owner to attempt a do-it-yourself project. There are varying opinions concerning the wisdom of this approach. Certain manufacturers all but insist that any additions or alterations to their systems be performed by the manufacturer's crew. The owner runs the risk of making his system unserviceable, they say.

On the other hand, there are case histories to demonstrate that an owner can do it himself under certain conditions. These conditions include the existence of properly trained mechanics on the owner's staff and the full cooperation of the manufacturer. The manufacturer should design the addition or alteration, prepare shop drawings, sell the hardware "over the counter" and then provide field supersion as requested. Both Honeywell and Johnson Controls have been known to function in this manner, and the other manufacturers may do so also. The advantages of system extensions by the owner's forces are obvious. The installation cost should be substantially less. Also, familiarity with the system instills confidence in the owner's staff and should improve maintenance capabilities.

Should the owner by choice or circumstance not wish to undertake construction work, he will have to deal completely with the manufacturer. This can be ameliorated by either threatening to or actually taking bids from manufacturers other than the existing one. This leads us to the subject of interfacing.

Interfacing

Apples and Oranges?

Perhaps no other subject in the CCMS field is more debated and less understood than the matter of interfacing of Brand "H" system with Brand "J" or "P," or vice versa. The major manufacturers strongly discourage the concept of mixing systems, although some will admit that it has been done somewhere but that the degree of success is unknown. The newer, smaller, hardware-oriented companies claim that interfacing is no real problem. A newcomer to the field, Compuguard, Inc., states, "The Compuguard System can be interfaced with the Honeywell Delta 2000 and 1000, Johnson JC-80, Powers 570, Robertshaw DMS 2400 and IBM System 7. Computers have no trouble talking to each other and Compuguard has both the hardware and software to support this interface."

The feasibility of a combined system is unknown. It seems logical that a black-box, software-oriented interface could, through use of interpretive programs, allow two different systems to work together. This may be possible but, if implemented, could present responsibility assignment problems. It is conceivable that both parties could disclaim responsibility for a malfunction that was detected across the interface. The original installation manufacturer would naturally blame the new firm for any problems in any way related or passing through the interface. After all, he (the original vendor) said it couldn't be done.

There could be at least four sets of circumstances that might suggest an interfacing situation. These are:

- owner dissatisfaction with present manufacturer
- a large addition, which due to its size and value warrants competitive bidding
- certain government projects that may not permit sole-source purchases
- obsolescence of an existing system for which the original manufacturer cannot provide a standard interface device

Should you decide to invite an interfacing situation, it is suggested that some safeguards be invoked. One approach that should secure the desired result is to require that the new system manufacturer provide:

- documentation on the method of infacing
- a list of operational systems on which he has successfully demonstrated interfacing techniques
- full service on the existing system in regard to those portions working through the interface. This reduces the problem of split responsibility. (It also may price the new manufacturer out of the competition.)

New Tangerine with an Old Orange?

A unique situation has arisen in the industry in which a major manufacturer (sales in excess of 40 percent of the entire market) has introduced a new line of equipment that is less expensive and more flexible than the previous line but superficially appears incompatible with the previous offering. The manufacturer is Honeywell, the new equipment is the Delta 1000, and the old is the Delta 2000. The Delta 1000 was initially offered as an inexpensive system for moderately sized single buildings. As its capacity grew with an increase in microprocessor power and memory, the new system is being offered in lieu of the older Delta 2000 for multiple building installations. On additions to existing campuses, this brings up the problem of interfacing. Initially, it appeared that the manufacturer intended the older, more expensive CPU to be the "leader" or driver for a combined system. However, as the new system emerges as a more flexible and more powerful product, the decision was made to let the new system "drive" the old through an interface device. This arrangement is reported to be more flexible and less expensive than upgrading the Delta 2000 by adding a Honeywell 316 minicomputer.

CHAPTER VI

PROCUREMENT PRACTICES AND IMPROVEMENTS

TRADITIONAL APPROACH

ADVANTAGES AND DISADVANTAGES OF THE TRADITIONAL APPROACH

ALTERNATIVE: A PERFORMANCE SPECIFICATION AND TECHNICAL PROPOSALS

PROPOSED EVALUATION USING VALUE/ANALYSIS TECHNIQUES

WHICH APPROACH?

CHAPTER VI

PROCUREMENT PRACTICES AND IMPROVEMENTS

Traditional Approach

Historically, building automation procurement has been handled in two ways. In new building plan and specification work, the contracting architect and engineering (A & E) firm prepares specifications. The specifications are often written around a certain manufacturer's standard specification. The bidding specification usually includes the name of the favored manufacturer and the names of acceptable alternative manufacturers, or the phrase "or approved equal." Use of this method may enable the favored manufacturer to include in the specification subtle "spec stoppers" that discriminate against the other bidders. These spec stoppers usually take the form of detailed descriptions of particular pieces of hardware or a particular sequence of control, both of which are proprietary. Needless to say, the other bidders probably can achieve the same result but cannot manufacture hardware identical to that of the favored manufacturer. Often, the other named manufacturers will take a shot at bidding the project, and if the A & E is not unduly partial to the favored manufacturer, the outsider may receive the control subcontract.

The other historical method of procurement is the "flat spec" approach, which is usually adopted for building add-ons or in new buildings for an existing complex. In this situation, the owner is reluctant to mix control hardware on the same project. The reasons for this approach are obvious. Most of us have been exposed to projects that have split responsibilities. When something goes wrong, especially during the "free service" warranty period, fingers are usually pointed at the other guy, implicating him as the responsible party. Of course, the other party goes into the same act.

These historical methods of procuring building automation have carried over into the world of Central Control and Monitoring Systems (CCMSs). The situation is perhaps more acute in the CCMS arena because of the vast differences in system design from one manufacturer to the other. As mentioned in Chapter V, just when everyone seems to understand the hardware scenario, one or more manufacturers break from the pack to market a brand-new system with different hardware and software. New claims are made and new spec stoppers are developed to gain and maintain a market advantage. This is not in itself bad. Technological improvements are constantly being made and no one wants an obsolete system. However, a decision must be made at some point in time to go ahead. If you are lucky (it almost always involves luck), the system chosen will perform as expected and will stay current for the foreseeable future.

Advantages and Disadvantages of the Traditional Approach

Needless to say, the traditional approach to CCMS procurement generally leads to a comfortable solution to the problems, presuming the A & E specification did in fact accurately represent the owner's needs. Of course, there can be communication breakdowns between the owner and the design team. Usually, if the favored manufacturer receives the CCMS contract, there should be high expectations of a satisfactory result. This is due to two factors. The first is that the manufacturer probably has at least a 10 percent cushion in his proposal, which he would relinquish if exposed to severe competition bidding. This cushion gives him some room to provide more than the usual service, thus making the owner and the A & E happy. The other factor is one of natural pride in a project that is "his" from the outset. There should be no misunderstanding about what is expected. This is not always the case, however. Manufacturer's literature covering system performance is often pie-in-the-sky advertising providing few or no detailed specifications. An energy management program may have been sold on the basis of a general description of the program. When on-line, it is determined that the program allows for only a few controllable loads (instead of the

hundreds necessary) and that the cycled loads may only be cycled twice a day (instead of twice an hour or more). It seems essential to clearly define every function that the CCMS is expected to perform. This approach will bring to light any weaknesses in the prospective system.

Another area of disappointment that is sometimes encountered in the traditional approach is the real or imagined feeling that the system is overpriced. This is especially true when add-ons are undertaken. It is bad enough to have suspicions concerning a manufacturer's "best price," but it is really worrisome when the other manufacturers volunteer to inform you that the real value of the work is 20 percent lower than the price paid.

Alternative: A Performance Specification and Technical Proposals

An alternative to the manufacturer-oriented or "hardware" specification is the performance specification that solicits bids together with technical proposals. The concept is to describe what you would like to have and then review proposals that attempt to meet the stated requirements. The technical proposal is evaluated as to compliance with the performance specification and then rated in some manner with price factored in to provide a combination of values to permit selection.

Although not explicitly stated in the above performance specification, it would seem desirable to receive technical proposals describing the bidders' hardware, approach, capabilities, etc., so that price along is not the sole deciding factor. Upon receipt of the technical proposals, it is desirable to have a formal method for evaluating the proposals. Several manufacturers have developed evaluation criteria that are intended to assist a prospective purchaser in making an objective evaluation of proposed systems.

Unfortunately, as might be expected, it appears that the questions asked by the evaluation sheets lead the purchaser down the "primrose path." Following is a sample of a more objective evaluation form that should be helpful in the evaluation process. The project engineer should modify the evaluation parameters to suit the project in question. The percentages assigned to the "categories" are purely subjective, as are the evaluation points. These items should be examined and revised to approximate the needs of the project.

Which Approach?

Each approach has its advantages. The traditional method has worked reasonably well for a number of years and should not be discarded arbitrarily. The performance specification-technical proposal approach has inherent appeal as it seems to encourage "letting the best man win." A word of caution should be interjected here. There are more than 200 minicomputer manufacturers in the United States alone, and there are probably as many computer application "experts" who would like to use your project as their guinea pig or springboard to fame and fortune. Any specification, either traditional or performance, should have qualification safeguards clearly defined. A safeguard such as requiring a minimum of "X" number of similar successful systems in operation for a minimum of "Y" years is an appropriate clause to be included, especially in government-type bidding documents. Verification of the listed satisfactory projects should be made before awarding the CCMS contract.

In the private sector, the physical plant procurement office may wish to examine all bidders, whether they meet the qualification clause or not. It is possible that there may be responsible new entries into the field that may be worth taking a chance on. In the private sector it is presumed that an unqualified low bidder can be rejected without hearing complaints or feeling pressure from that bidder's elected representatives.

PROPOSED EVALUATION USING VALUE ANALYSIS TECHNIQUES

VALUE ANALYSIS FOR SELECTION OF
CENTRAL CONTROL AND MONITORING SYSTEMS*

Instructions for Using Evaluation Sheets

Since the use of these forms involves a qualitative judgment, it is necessary that:

1. All vendors be analyzed at the same time to obtain comparative analysis.
2. Analyzing should be done before opening bids to ensure objectivity.

The categories to be analyzed should be selected and then assigned a percentage of importance to the total project. Each percentage is then put into a box in the upper right-hand corner.

NOTE: This number multiplied by 10 will be the maximum value that each category can receive. Total value for all categories will equal 1,000.

The attached evaluation has a category breakdown as follows:

Category	Percentage	Number for Box	Maximum Total Number
Vendor Capabilities	20	20	200
Central Processing Unit	20	20	200
Field Monitoring/Control	15	15	150
CPU Operation Software	15	15	150
Energy Conservation	15	15	150
Fire/Security	10	10	100
Maintenance Management	5	5	50

Maximizing Value

1. Each category has a list of items and a number within a box in the upper right-hand corner. Each item has a value of 0 to 10, with 0 = not complying and 10 being perfect.
2. Cross out items that are irrelevant. This will be especially true in areas of program options that are not required.
3. Place asterisks on items that are mandatory. Every one must have a value to qualify.
4. a. Assign values to each item (1 to 10)
   b. Total of values = x
   c. Total of items = y
   d. Divide x by y and multiply by number in box.
5. Add total of all values for the final score, or number of value points.
6. When bids are received, divide system price by total value ($ ÷ value points = K). Do this for each bidder. Compare Ks of the qualified bidders. The system with the lowest K is the best buy. However, variations of 5 percent between vendors should not be considered significant due to the subjective nature of the valuation point process.

*Prepared by: Johnson Control, Inc., Baltimore, Maryland.
(Revised and reprinted by permission.)

A. Vendor Capabilities (consider local and national) [20]

1. Stability--number of years in business _____
2. Number of similar systems installed and operational _____
3. Reliability of installed systems (points functioning properly ÷ total system points) _____
4. Quality of proposal _____
5. Project Plan--schedule and method of determining progress _____
6. Guarantee _____
7. Service--normal response time and availability of emergency service _____
8. System training--documentation and instruction for operations _____
9. Installation responsibility--total versus split _____
10. Maintenance Agreement--duration, terms _____

NOTES: 1. Grade each item on a scale of 1 to 10.
2. Add all grades and divide by 10.

Maximum number possible is 200.

B. Central Processing Unit--Hardware/Software [20]

System Overview

1. Suitability to project--is the motif of consoles, processor, equipment cabinets, etc., state of the art? _____
2. Modularity--are sections modular enough so only required sections need to be purchased? _____
3. Ease of installation--modularity, number of connections, etc. _____
4. Growth Potential--will the control center, including peripherals, accommodate all future growth? _____
5. Ease of Revision--can the control center be easily revised with the use of a minimum of plug-in cables? _____

Software

6. Suitability to project--standard programs corresponding to this application _____
7. Modularity--expansion/contraction of programs _____
8. Flexibility--ease of modifying/adding or deleting. Field or factory reprogrammable? _____
9. Expandability--accommodate additional points _____

Hardware

10. Central Processing Unit (CPU)--State of the art, basic memory capacity, expandability, compatibility with bulk storage _____
11. Flexibility--ability to substitute and/or add peripheral devices _____
12. Cathode Ray Tube (CRT)--display size/alarm indication and screen format _____
13. Printers--number, type, speed, message format _____
14. Keyboard--full alphanumeric, active with other keypads and keyboards, dedicated function keys? _____
15. Accessories--projector, tape punch, etc. _____

NOTES: 1. Grade each item on a scale of 1 to 10.
2. Add all grades and divide by 15.

Maximum number possible is 200.

C. Field Monitoring/Control

15

1. Suitability to project--is present-day state of the art employed? _____
2. Capacity--is system design capable of standardly handling all inputs? _____
3. Method of transmission--digital/analog and coax/multiplex _____
4. Analog accuracies--.1F, .5F, 1F _____
5. Signal protection--noise immunity on communications from CPU to field processing system _____
6. Command function integrity--verification of all command signals before execution _____
7. Circuit protection--protection of foreign voltages from sensor areas into logic circuits _____
8. Speed of response--maximum time for a binary field change to report _____
9. Compatibility of field system to peripherals easily added at field locations _____
10. Input data advisory--advises operator that field panel is no longer receiving data from CPU _____
11. Output data advisory--notifes operator that field panel can no longer send data to CPU _____
12. Primary power advisory--advises operator that primary power in panel has failed _____
13. Secondary power advisory--secondary power in panel has failed _____
14. Tampering advisory--card has been removed from panel or door is open _____
15. No response advisory--a point will not communicate with CPU _____
16. Sensors--averaging elements in ducts _____
17. Sensors--precision/repeatability _____

NOTES: 1. Grade each item on a scale of 1 to 10.
2. Add all grades and divide by 17.

Maximum number possible is 150.

D. CPU Operation--Software

15

1. Date--numeric versus alphanumeric and day of year versus day/month/year _____
2. Password protection--levels and assignments _____
3. Password system--integrated in system or add on _____
4. Operator input--English language vs code _____
5. System output--English language vs code _____
6. Index of buildings--to reveal systems within a building _____
7. Display of system or points with automatic slide display _____
8. Alarm summary _____
9. Summary of analog limits with differentials _____
10. Summary of points locked out _____
11. Summary of program start/stop times including days of week _____
12. Summary of security points in secure _____
13. Summary of security points in access _____
14. Summary of program access/secure times including days of week _____
15. Two-position field command--start/stop _____
16. Three-position field command--start/stop/auto _____
17. Remote adjust of set point/damper _____
18. Unlock/lockout of selected points _____
19. Intercom selection--single/all call _____
20. Message service--communication between CPU and peripheral, peripheral and CPU or peripheral and peripheral _____
21. Trend log--12 points _____
22. Add/delete trend points--ease of achieving _____

D. CPU Operation--Software (continued)

23. Analog limits/differentials--individual vs group _____
24. Changing of analog limits/differentials--normal operator input vs special procedure _____
25. Program start/stop times/days, individual vs group _____
26. Changing of program start/stop times/days, normal operator input vs special procedure _____
27. Program access/secure times/days, individual vs group _____
28. Changing of program access/secure times/days, normal operator input vs special procedure _____
29. Priority output for change-of-state/fire points before HVAC _____
30. Ability to assign specific change-of-state points to specific output devices _____

NOTES: 1. Grade each item on a scale of 1 to 10.
2. Add all grades and divide by 30.

Maximum number is 150.

E. Energy Conservation Programs [15]

Totalization

1. Totalization method--hardware vs software _____
2. Long-term maintenance _____

Enthalpy

3. Number of psychometric regions covered _____
4. Accuracy of measurement _____
5. Time interval update _____
6. Action taken--manual vs automatic _____

Supply Air Reset

7. Accuracy of measurement _____
8. Time interval update _____
9. Action taken--manual vs automatic _____

Electric Demand Prediction/Load Shed Restore

10. Prediction vs ideal rate _____
11. Time interval update _____
12. Accuracy of measurement _____
13. Action taken--manual vs automatic _____
14. Flexibility in load assignments _____
15. Manual back-up during CPU failure _____

Load Rotation (Duty Cycle)

16. Number of schedules available _____
17. Number of steps, each schedule _____
18. Number of assignable loads per schedule _____
19. Automatic adjustment of "off" period to suit space conditions _____
20. Operator interrupt and reassignment of loads and schedules _____

Optimization

21. Basic chiller package--measurement and resultant output _____
22. Automatic readjustment of the chillers based on building demand _____
23. Printout of chiller efficiency--on command or fixed intervals _____
24. Accuracy of measurement _____
25. Basic optimum start program based on outside air temperature, system capacity and controlled environment _____
26. Uncontrolled environment to reduce run time of the building equipment controlled by optimum start program _____

E. Energy Conservation Programs (continued)

27. Accuracy of start-up determination _____
28. Time interval updates _____

NOTES: 1. Grade each item on a scale of 1 to 10.
2. Add all grades and divide by 28.

Maximum number if 150.

F. Fire/Security 10

Fire

1. Suitability to project--integrated vs. add on _____
2. Certificate of installation with total verification _____
3. Supervision of initiated modules _____
4. Supervision of signal modules _____
5. Approvals (UL, FM) _____
6. Smoke detectors--ionization-photo _____
7. Heat detectors--rate of use, fixed temperature _____
8. Manual pull stations _____
9. Bells/horns--compliance _____
10. Standby power _____

Security

11. Suitability to project--integrated or add on _____
12. Supervision of initiated modules _____
13. Supervision of signal modules _____
14. Approvals (UL) _____

Badge Access

15. Number of possible readers _____
16. Time programs available _____
17. Quantity of inputs _____
18. Operation during CPU failure _____
19. Flexibility to add/delete _____
20. Protection of system from unauthorized changes _____

NOTES: 1. Grade each item on a scale of 1 to 10.
2. Add all grades and divide by 20.

Maximum number is 100.

G. Maintenance Management 5

1. Suitability to project--integrated vs add on _____
2. Work order program--clarity and completeness _____
3. Maintenance scheduling and work order program--content, description, etc. _____
4. Maintenance forecasting--content, etc. _____
5. Maintenance action--method required _____
6. Cost summary program--type, content, etc. _____
7. Management reports--types, such as skill, tasks, etc., and content _____
8. Update of work orders into CPU _____
9. Performance index input _____
10. Run time input _____
11. Flexibility for making changes _____

NOTES: 1. Grade each item on a scale of 1 to 10.
2. Add all grades and divide by 11.

Maximum number is 50.

CHAPTER VII

INSTALLATION PROBLEMS AND SOLUTIONS

CONSTRUCTION SUPERVISION
- The Contractor
- The Owner
- The Architect and Engineering Firm (A & E)

SUITABILITY OF HARDWARE
- Shop Drawing Review
- On-Site Verification

TRANSMISSION SYSTEMS
- Cable
- Lease Line

CHECKOUT AND ACCEPTANCE
- Component Level Tests
  - Operational Test for Sensors, Control Devices
  - Functional Test for Data Collection Panels
  - Functional Test for CPU and Peripheral Equipment
  - Wiring/Tubing Tests
  - Electrical Wiring Tests
  - Cable Termination Tests
  - Pneumatic Air Line Tests
- System-Level Tests
- System Acceptance Tests

GUARANTEE AND SERVICE

CHAPTER VII

INSTALLATION PROBLEMS AND SOLUTIONS

Construction Supervision

The Contractor

This section assumes that a Central Control and Monitoring System (CCMS) has been designed, specified, bid and awarded to a contractor who probably is the low bidder, on government projects at least. Let us further assume that the contractor hasn't lost any money to this point so that only optimistic thoughts pervade the project.

The contractor is required to submit a project management plan as early as possible after award of the contract, usually within 30 days. The project management plan should consist of at least the following components:

- organizational chart, indicating project team members, i.e., project manager, field superintendent, foreman, etc.
- program plan including a statement of tasks
- project schedule depicted by Gantt chart and Pert/CPM procedures
- reporting format
- submittal procedure
- program meeting arrangements

The Owner

The owner, who we will assume is the using agency, will assign one or more full-time representatives to follow the project. At least one of the owner's representatives should be someone who has been associated with the project from the outset. Assigning a new person to the key construction representative position is inviting problems. The owner's representatives should study the contractor's construction plan and document his progress. The usual field representative tasks include shop drawing review, daily inspections, attendance at progress meetings and verification of requisitions. The owner's staff is responsible for coordinating construction activities with building occupants. The owner's representatives should anticipate and coordinate the usual building shutdowns and similar inconveniences.

The Architect and Engineering Firm (A & E)

The Architect and Engineering Firm (A & E) is usually required by contract to perform construction-phase services. These services typically include:

- checking shop drawings
- periodic site visits
- approving requisitions
- issuing change orders
- verifying performance of completed work
- attending progress meeting
- preparing "as-built" drawings

Suitability of Hardware

Shop Drawing Review

Perhaps the most important task in the construction phase of a project is shop drawing review. This is the point at which the contractor's intentions are made clear. Ideally, he has taken no exceptions to the project specifications, and where there exists any doubt about the level of quality, he will offer a product that exceeds the minimum requirements. It is at this point that it pays to read all of the fine print. Failure to do so can result in serious problems later on. Although the shop drawing reviewer is not legally responsible for deficiencies that he misses, it is far better to discover potential problems at the shop drawing phase before the work is installed. Fine-print items, such as environmental requirements of DCPs, electrical characteristics of central equipment, lease telephone line requirements or requirements for accessories that are not standard but necessary, can be easily missed and have serious implications in the performance of the system. Panels and cards specified to have factory burn-in periods should be checked for certification.

On-Site Verification

Every piece of hardware that is received on the job site should be examined to ensure that it is the proper make and model number as indicated on the approved shop drawings. Any piece of doubtful equipment should be rejected immediately. Proof of suitability or replacement should be required. The handling and storage of electronic equipment, especially the central station gear and the DCPs, should be closely monitored. If possible, shipment of complex equipment should be timed to avoid prolonged site storage.

Transmission Systems

Defective data transmission systems have caused the demise of many CCMSs. Certain basic precautions must be taken to ensure against transmission difficulties.

Cable

Transmission cable is usually coaxial cable or a twisted pair. The success of this system link is dependent upon adequate protection from physical damage. Cable between buildings should be run in concrete-encased conduit. Direct burial or overhead lines must be avoided for system integrity. Lighting protection and grounding procedures must be strictly adhered to to prevent damage and/or faulty data transmission.

Lease-Line

"Lease-line transmissions" are frequently used words that have become almost a household phrase. Generally, however, very little is known about lease-line transmission. Specifications call for voice grade suitable for transmission of data at 1200 baud. Sometimes the mention of an unconditioned, 3002 channel is made along with the voice-grade requirement. Usually, when dealing with a Bell System company, no further requirements need be stated. Coaxial cable is brought to the modem (the phone line interface unit), and the telephone company does the rest. Trouble can and does arise where private or government phone companies maintain the phone systems. It is then necessary to be more specific.

Besides meeting the voice-grade requirement, what is really needed is a four-wire, full-duplex transmission system. The two-wire, half-duplex system should be avoided as trouble may well result, especially if multiple buildings are brought back to a central office via phone lines. There is virtually no way to maintain the required 600-ohm balanced circuit over parallel two-wire lines.

Checkout and Acceptance

Component-Level Tests

These tests are conducted at two levels, in the plant prior to shipment and in the field.

Operational Test for Sensors, Control Devices

1. Check each installed transducer for construction detail quality.
2. Check each installed transducer for wiring quality and proper termination.
3. Electrically check each installed device for signal output (voltage and impedance).
4. Properly calibrate each device.

Functional Test for Data Collection Panels

1. Check the mechanical installation of each DCP.
2. Check all wire terminations at each DCP.
3. Check a sample of the wiring between DCPs and CPUs for correctness and impedance.
4. Check each DCP for:
   a. power supply voltage levels.
   b. operation of standby power supply.
   c. logic levels on the DP data and control bus.
   d. sample inputs and outputs at the function cards.
   e. operation of Class A supervision at each DCP.
5. Simulate data and control signals over the sensor and controls, measuring I/O parameters.
6. Simulate data and control signals

over the transmission system measuring I/O parameters.

Functional Test for CPU and Peripheral Equipment

1. Check mechanical installation.
2. Check wiring terminations.
3. Check power supply voltage levels and standby power operation.
4. Check CPU for data and control signals.
5. Check contents of memory modules.
6. Check I/O parameters at each interface card, modem and plug-in module.
7. Run the CPU under test software, to check hardware and software operation.
8. Check operation of the CPU. Simulate incoming data displays and system/control commands under test software.
9. Check operation of remote consoles.
10. Check operation of all other printers.
11. Check audio communications between central console and all remote printers.
12. Check data communications between components of the central console.
13. Check operation of the transmitter/recorder feature at the central console (NFPA 73).
14. Check acknowledgment function at the printers in the fire stations.
15. Simulate system data and control functions on the incoming data cables.

Wiring/Tubing Tests

These are primarily tests to check the integrity and quality of all wiring/tubing installed.

Electrical Wiring Tests

These tests include:

- insulation resistance tests.
- conductor continuity and impedance tests.
- frequency response tests.
- EMI/RFI tests and ambient noise tests, on a sampling basis.

Cable Termination Tests

These include quality control checks of:

- workmanship at the terminations.
- accuracy of terminations.

Pneumatic Air Line Tests

These tests include:

- blowing of air lines.
- line pressurization tests.
- leak tests at joints (soap tests)
- termination checks.
- line integrity tests.

System-Level Tests

System-level tests are conducted in stages, along two parallel hierarchies:

Location	Type
point	binary/analog/control type
building	existing/new subsystem
subsector	subsystem type (e.g., fire, security, HVAC)
sector	system

For each of these major categories, the following tests are conducted:

- alarm test, fire/intrusion alarms
- alarm test, other alarms
- change-of-status tests
- analog monitoring tests
- control (binary) test
- control (analog) test
- data transmission tests, for data accuracy
- command control network tests, data and audio communication
- operator system interface tests
- operator response tests
- fire/intrusion alarm tests, for compliance with NFPA 72 (A-3) and 73

System Acceptance Tests

These tests will be documented ex-

tensively, and most will be conducted in the presence of the contractor, the owner's representative and the A & E representative. The satisfactory completion and documentation of these tests will be followed by system acceptance. Operational performance reliability should exceed 95 percent before acceptance.

Guarantee and Service

The entire system should be guaranteed for two years after acceptance of the system. The acceptance may be made in stages as the owner takes over the use of the system. During the guarantee period, the contractor should perform all service, both routine and emergency type.

The contractor should furnish to the owner the following:

- instruction books
- replacement part information with recommended stock levels of needed items. The items and quantities noted should be provided to the owner for the initial inventory of spare parts.
- schooling, at no expense to the owner, to train at least two of the owner's maintenance mechanics to maintain and repair all parts of the system with the exception of the central I/O devices. Details of this requirement should be included with each contract bid proposal.
- as-built drawings of the hardware configuration
- a firm proposal for each bidder for each of the following types of maintenance programs:
  --total
  --emergency
  --periodic inspections
  The cost of this service should be adjusted according to some acceptable preassigned economic cost index. The selected service should be available for a minimum period of 15 years.
- test and analysis equipment to provide the owner's maintenance personnel with complete field troubleshooting capabilities.

CHAPTER VIII

PERSONNEL AND TRAINING

PERSONNEL
- Objectives
- Selection
- Assignments

TRAINING
- Types Available
- Basic Operator Training Course -- Entrance Level
- CCMS Operation Training
- Computer System Operation Training
- Cost
- Which Training Program?

CHAPTER VIII

PERSONNEL AND TRAINING

Personnel

Objectives

Before a Central Control and Monitoring System (CCMS) project begins, all departments and personnel who may be affected by the project should be advised of the program. This can be done on an informal basis, in a newsletter article or in a special bulletin. The emphasis should be based on the general expectations of the institution and how the system will help everyone. The fear that employees are being replaced by a computer should be attacked head-on with candid statements explaining the personnel requirements associated with the pending installation. Usually, campuses are understaffed, so that the CCMS does not replace anyone but does permit the physical plant to do a better job with the people already on hand. Favorable publicity should be generated on a regular basis to keep the project in the limelight.

One major objective is the achievement of a positive attitude among the personnel who will be involved with the CCMS. The success or failure of the CCMS installation in no small way depends upon the attitude of the personnel who will interact with the system. It is essential that the staff assigned to operate the system be aware of the pending system and that they become familiar with the hardware and operational format. Familiarity, hopefully, minimizes any threat that the CCMS may present to the staff. Ignorance breeds fear and negative reaction. Knowledge and understanding instill confidence and promote positive response.

Selection

The consulting engineer should assign a suitable project engineer to head up the project and work closely with the university from the outset. He should be familiary to the university staff and be thoroughly experienced in the design of the CCMSs.

The owner must select the key individual who will head up the project for the university. This is a key administrative position and should be filled at the level of assistant director of physical plant. This assistant director should be a mechanical or electrical engineer knowledgeable in both disciplines. The individual is responsible for advising the physical plant administrator on the selection of a team from the physical plant department to become the CCMS team. This group would be instructed in the basic principles of the CCMS, be familiar with the economic justification for the system and be trained in the hands-on operation after the system has been installed. The number of personnel selected will depend on the size of the campus and the system selected.

Assignments

At the University of Monnesota, a Honeywell Delta 2500, with over 5,000-point capacity serving three campuses, is staffed as follows:

1. For normal working hours, 8 a.m. to 4 p.m., a senior plant engineer and a principal engineering assistant handle such responsibilities as the development of systems for new buildings, establishing programs of operation and engineering studies and supervision of the CCMS.
2. From 4 p.m. to midnight, Monday through Friday, one regular employee serves as CCMS operator.
3. From midnight to 8 a.m. weekdays and around the clock on weekends, student operators assume responsibility. These are usually mechanical engineering work-study students who work full-time one quarter and attend classes full-time the next quarter.
4. Maintenance of the system is performed by two full-time electronics technicians and one part-time electronic technician, who is a student.

Training

Types Available

Training programs offer varying levels and intensity of instruction. The minimum is two eight-hour days of on-site instruction for the CCMS operators. The second level of instruction for console operators includes factory instruction in addition to field instruction. The next level of instruction is intended to train maintenance personnel in basic troubleshooting routines required for maintenance of DCPs, peripherals and low-level maintenanc of the CPU. The highest level of training includes the theory, operation, programming and troubleshooting of the computer.

On small systems, field training of console operators will usually be adequate to keep the system operational. The initial two eight-hour days of instruction are normally broken up into short periods of two- to four-hour increments. This approach allows the operator to absorb as much as he can in one session and then to practice what he has learned. When the first session "sinks in," another instruction period is scheduled. It is desirable to have two to four of the staff receiving these instructions. This group would include two operators, the building engineer and the department head who is responsible for the operation of the CCMS. The operator's manual furnished with the CCMS would be used extensively in the field training.

The second level of instruction for console operators is conducted for three days at the factory. This course of study study approximates the instruction given in the field but is more intensive and presumably better staffed. The factory facilities are utilized for instruction, affording better training aids and teaching staff than locally available.

A course outline of a typical three-day factory training course follows:

Basic Operator Training Course-- Entrance Level, Three Days

A. Objectives:

1. to learn to operate central console keyboard
2. to learn to recognize malfunctions
3. to learn to use the CCMS in conjunction with building mechanical equipment
4. to learn how to make changes in the CPU memory program
5. to learn the basic DCP functions and applications

B. Prerequisites:

The student should be responsible for operating a CCMS console. It is desirable but not mandatory that the operator be familiar with the functions of the mechanical equipment he is to monitor and control. Some previous experience on mechanical systems operation is also desirable.

C. Content:

This course introduces the CCMS to the new operator in terms of the overall system function, major components and their functions and the basic skills necessary to operate the system. The operator's manual is used as a prime source of reference in the course.

D. Course Administration:

This course is run on request or where there is sufficient enrollment. It may be run either at the factory, the branch or the owner's premises, depending on the local facilities and the number to be trained.

The next level of instruction presupposes that the student possesses an elementary background in electronic theory and computer operation. A course outline of a typical three-week, medium-level training course at the factory follows:

CCMS Operation Training, Three Weeks

A. Objectives:

1. to learn to troubleshoot the data collection panels
2. to learn the theory of CCMS message transmission
3. to learn to program the CPU memory
4. to learn system checkout and troubleshooting procedures
5. to familiarize the student with the circuitry and operation of the CPU

6. to enable the student to use logic-probe and card-replacement procedures
7. to learn troubleshooting techniques for the CPU
8. to learn to analyze symptoms for troubleshooting
9. to learn to locate problems (broken or shorted wires, defective transistors and connections, blown fuses, etc.)

B. Prerequisites:

The student should have an understanding of basic logic including:

and, nand, or, nor, and exclusive or gates, latches, flip flops, both rs and jk, counters, registers and read-only memories.

Logic symbols and notations must be understood, as well as binary, BCD, octal and decimal number systems. The student should be familiar with the operation of the system at his facility and have responsibility for its operation.

C. Content:

The course covers the theory and operation of the entire CCMS. The remote panels. the CPU and their relationship to the mechanical systems they control are covered in detail. The course includes diagnosis of remote panel problems as well as checkout and troubleshooting of the CPU. Programming of the memory will also be covered, including hands-on loading of a memory program. This course covers only the technical automation aspects of the system and will not by itself equip the participant to completely maintain his HVAC automation system.

The highest level of training includes the theory, operation, programming and troubleshooting of the computer. A course outline of a typical three-week factory training course follows:

Computer System Operation Training, Three Weeks

A. Objectives:

1. to learn the function of the computer addition to the basic CCMS, including available software packages
2. to learn the operation of the computer, the peripherals, computer interfaces and the CRT terminal
3. to learn basic programming, including both program reading in the computer and the writing of troubleshooting programs
4. to learn how to load programs either manually into the computer, through the CRT terminal using debug or using a high-speed tape reader
5. to learn functions of disc and cassette tape options

B. Prerequisites:

The student must have successfully completed the intermediate-level course and should be responsible for maintaining a computer-based CCMS. A knowledge of digital electronics is necessary.

C. Content:

The course covers the theory, operation, programming and troubleshooting of the computer as it is used in the CCMS. Training on the operator's console is included as well as the interfaces between the computer, disc, operator's console and printers. Laboratory sessions comprise about 40 percent of the course, during which problems are simulated which the students must locate and correct.

D. Course Administration:

This course can be conducted at the factory or at the owner's facility, provided he has suitable classroom facilities, a working computer-based CCMS that can be used during hands-on sessions and sufficient personnel to warrant conducting it at his location.

Cost

The cost of training programs is fairly uniform throughout the industry. The least expensive training, of course, is the on-site operator instruction. This may be given in part by direct factory personnel and in part by local sales and service organizations.

The training programs given at the

factory are fairly expensive but not prohibitive. The charges run from $80 to $100 per class day. The three-day factory course is at least $300 plus transportation, meals and lodging. The three-week courses range from $1,200 to $2,000 depending upon course content and upon the number of students enrolled.

Which Training Program?

The decision as to which training program to pursue depends upon several factors. As mentioned earlier, system size has the greatest effect on the magnitude of the investment of time and tuition. Certainly, a small building of 100 points would justify nothing more than on-site training. Of course, a system that small would not warrant a computer-based system, either.

A comparison of training cost relative to the overall cost of the CCMS may be of value. Most campus-wide systems start around $1 million and go up from there. Several thousand dollars spent on training represents a small percentage of the overall expenditure and sounds like a good investment.

It is essential that the proposed trainee be mentally and emotionally capable of receiving the intended training. If the trainee lacks the basic ability and/or the interest, then the expenditure should not be made. Better yet, the proposed trainee should be replaced with someone better suited to the requirements of the CCMS operation. Usually, prospective trainees are eager to attend classes as it allows them to broaden their capabilities and in turn makes them more valuable to the university. That point can be a potential problem, however. More than one newly trained technician has been lured away to a higher-paying job soon after receiving all-expenses-paid training. It is somewhat of a gamble. However, it seems wise to make a heavy commitment to a training program. Good results usually accrue to the owner.

CHAPTER IX

OPERATING AND MAINTAINING A CENTRAL CONTROL AND MONITORING SYSTEM

DETERMINING REQUIREMENTS

UNIVERSITY OF MINNESOTA CENTRAL CONTROL AND MONITORING SYSTEM
- Introduction
- Central Control and Monitoring System Design
- Personnel

APPLICATIONS OF THE CENTRAL CONTROL AND MONITORING SYSTEM
- General
- Analysis
- Radiation Systems Temperature
- Radiation-Reheat Systems Pressure
- Domestic Hot Water Tank and Supply Temperature
- Supply Fans with Overheated Plenums
- Supply Fans with Improper Volumes of Fresh Air
- Heat Recovery Systems
- Animal Ventilation Off
- Roof-Top Temperature
- Steam Absorber Start/Stop
- Auditoriums
- Steam Flow to the West Bank
- Central Point Adjustment (CPA)

CENTRAL CONTROL AND MONITORING SYSTEM OPERATION
- General
- Fan Schedules
- Alternate Printer
- Improved Measure of Energy Use

MAINTENANCE

ROLE OF STUDENTS IN OPERATION AND MAINTENANCE

CHAPTER IX

OPERATING AND MAINTAINING A CENTRAL CONTROL AND MONITORING SYSTEM

Determining Requirements

The operating requirements of the system must be determined by management, with the help of the designer. The operation of a Central Control and Monitoring System (CCMS) constitutes a closed loop of information flow. To guarantee a working system, the following must be considered:

- reporting requirements of the system
- personnel and staffing
- training programs
- operating and emergency procedures
- automatic and manual report preparation
- evaluation of reports by management
- feedback to operating engineers from management

Too often, management does not recognize its responsibility to properly interface with the CCMS. To be effective, management must totally understand the system, recognize its potential, its weaknesses and capacity, and demand sufficient information from the system so that it can become a viable addition to the campus. CCMSs should not be left alone with inexperienced operators.

University of Minnesota Central Control and Monitoring System

Introduction

This chapter will examine the management and operations of the University of Minnesota CCMS. The management and operation of an automation center began with the history of automation at the University. The first unit was purchased on a bid basis in 1960. It was installed in the health sciences complex, and was to provide information on the critical fan systems and save steps filling out status logs. The unit was a multiplexer system, a central processor with a 50-fan capacity, hardwired. This was expensive to install and limited in capacity, but it was the state of the art at that time. This was before energy management became popular, but the idea was the same--saving dollars in both operation and labor. Cost analysis of this installation and its cost savings during its operation justified further installations of automation centers.

Central Control and Monitoring System Design

Because the University of Minnesota, Twin Cities campus, is not a single-location campus site, the development of automation took place by areas. The Minneapolis campus is divided by the Mississippi River and is classified as East Bank campus, which has about 90 major buildings; and West Bank campus, right across the river, with about a dozen major buildings. The St. Paul campus, first developed as an agricultural school and now also a diversified campus with about 50 buildings, is five miles east of the main campus. In addition, there are several University-owned and operated buildings one-half to three miles from campus in Minneapolis and St. Paul. One building, the Freshwater Biological Institute, is located 25 miles west of the main campus on Lake Minnetonka. And like other universities, it has coordinate campuses, including Duluth, Morris, Crookston and Waseca.

In 1963, construction of the West Bank campus began, including five buildings and 400,000 square feet. The experience in the health sciences complex automation center sold the idea of installing a unit on the West Bank. It would be operated with only one person on duty during the day. Maintenance and repairs were done on a job-order basis through the control shop. This unit is still in operation.

In 1965, administrators decided to install automation on the East Bank campus. Systems at that time had distance limitations, so it was necessary to purchase a separate system for the East Bank. The third system was purchased, installed and

connected to fifteen buildings.

During the years that followed, the University has expanded into buildings that are off-campus: personnel, administrative offices, computer center and some research laboratories. Buildings off-campus created maintenance and operating problems such as operating heating and air conditioning equipment. Fortunately, about that time, the state of the art of automation centers had developed to the point where system utilities could be monitored and controlled over leased lines--a natural for off-campus buildings. The decision was then made to establish a central building systems automation center to monitor and operate building systems equipment both directly wired on the Minneapolis campus and connected to telephone lines for off-campus buildings, the St. Paul campus and the Duluth campus. In smaller rented buildings, they installed only contact alarms to monitor boiler pressure, building temperature, fire alarms and security. These are also operated over telephone line. This system now has between 3,000 and 4,000 points connected.

The system design includes two printers, one for logging and one alarm printer. Both printers were replaced, because the first ones only printed at the rate of 10 characters per second. The system grew in size so that an "all points" log took approximately an hour and 20 minutes. When high-speed printers that print 100 characters per second were installed, the "all points" log required approximately 12 minutes.

The physical plant department keeps track of the entire operation from a central point. It has a hot line to the police department and serves as the contact office for night and weekend emergencies. Elevator emergency telephones are connected to the automation center, and a paging system is operated from the automation center.

A slave printer is installed in the police building. This unit receives printouts of all fire and security alarms. Fire and security alarms will print out on the printer in the automation center as well as in the police building. Constant contact is maintained with the police during these emergencies to receive instructions for whatever assistance physical plant is to provide.

Personnel

The automation center staff includes a senior plant engineer and a principal engineering assistant, whose responsibilities include developing systems for new buildings, modifying existing system operations, establishing programs of operations, doing engineering studies and supervising the automation center. One Civil Service person works as an operator on the 4 p.m. to midnight shift, Monday through Friday. A regular employee serves on that shift because the night school operation causes it to be an active period.

Student operators cover the other shifts, midnight to 8 a.m. and weekends. To cover these shifts, at least five students work part-time. Mechanical engineering students are sought for this program. The University fills the day operator position with mechanical engineering work-study students. Two students alternate every other quarter, working full-time one quarter and attending classes full-time the next quarter. Two full-time electronics technicians and one part-time student who is an electronics technician maintain the system.

Applications of the Central Control and Monitoring System

General

All control systems require periodic maintenance to obtain designed system performance. When many systems, each with several components, are grouped into an "automation center," maintenance becomes even more important and complicated. Because any monitored device may initiate an operational alarm representing a large variety of conditions and unique responses, the automation center becomes progressively more complex as many devices are added to the system. The criticality of maintaining 100 percent accuracy without downtime and making the correct response instantly when problems arise necessitates a focus on maintenance and operation of the CCMS.

Analysis

Even while these activities are being performed, nonalarm, noncritical data are also recorded for analysis. This type of analysis typically compares some value measured at the automation center (temperature, pressure, humidity or status of a motor) with time or outside air temperature. The duration and magnitude of the change determines how intensively the data are recorded. As standard procedure, at least once every 24 hours, all points are recorded. Despite the season, additional "all points" checks are taken whenever temperatures are between 45°F (8°C) and 65°F (18°C). A review for a general problem such as high mixed air temperatures might be examined once every three months, but a specific fan that seems to cycle discharge air temperature beyond limits will have several associated values recorded as often as every minute.

Student operators compile data and do some initial analyses during nights and weekends when the pressures for maintenance and operations are reduced. The plant engineers then review this initial analysis to determine if further studies may be needed, what design changes are necessary or which shop should repair the malfunction. Some examples of long-term studies follow.

Radiation Systems Temperature

Over two years, data have been recorded manually and entered into a computer used for typical academic engineering problems. The resultant curve for supply temperature versus outside air temperature can be compared with specifications to see if the system is working as initially designed. The energy crunch has allowed establishing new design criteria that are applied to all systems, but especially to those that are running at higher temperatures than designed.

Articles have appeared in the local newspaper encouraging occupants to call in complaints of too hot or cold space conditions. This, combined with the ongoing CCMS temperature study, helps to reevaluate new conditions to maximize comfort while documenting operational limits and expected values of supply and return temperatures, meanwhile conserving energy.

Determining extreme range alarm conditions is possible even with radiation systems that will be automatically reset by outside air temperature. During a typical day a system may not exceed the extreme limit, but may still be beyond the intended value for comfortable, conservation operation. Because of this, there will always be a need for periodic review and an easy means of updating the expected operation whenever design conditions change.

Radiation-Reheat Systems Pressure

The building height, system design and location of the sensor will indicate a minimum critical low pressure for circulation; the pop-off valve will provide a maximum high pressure. Operational values, however, are reviewed and analyzed to determine more typical values and also indicate an alarm limit which will allow nonemergency repair. Once initiated, periodic review will also show if a system is slowly losing pressure, which may indicate a small leak.

Domestic Hot Water Tank and Supply Temperature

There are a few exceptional areas on campus that require hot water at temperatures higher than 120°F (50°C). A monthly bulk alarm is initiated by the CCMS to find any domestic hot water that has crept away from this design. An hour trend at two-minute intervals is then initiated to find out if an unusual high or low cycle has occurred, or if repair is needed.

Supply Fans with Overheated Plenums

During the heating season, when a fan is stopped, the controls on the steam coils go to a normally open condition. This is a University design intended to prevent coil freeze-up, but it often means that the fan plenum becomes overheated. Once a week during the winter, all mixed air temperatures are reviewed. The values are taken about 2:30 a.m. when scheduled fans are off. Any fan that has a mixed air higher than 90°F (32°C) is checked in the field to see if the existing controls and dampers are working

properly. If they are, then possible corrections to the controls will be made to limit the duct temperature. Thus, temperatures are reduced and energy saved on overheated plenums, while still providing freeze-up protection.

Supply Fans with Improper Volumes of Fresh Air

These fans are found by reviewing the values of return air, mixed air and discharge air when the outside air temperature is between 55°F (13°C) and 65°F (18°C). At these cool temperatures most fan systems run with 100 percent fresh air; therefore, the discharge, mixed and outside air should all read the same. If not, field inspection should indicate corrective action. Similar studies are done in very warm weather or very cold weather when fresh air should be at a minimum.

Heat Recovery System

There are several types of systems to recover energy that are connected to the CCMS. Data are compiled chronologically in half-hour increments and also meteorologically with 1°F changes in outside air temperature. These data are then analyzed to determine if the actual recovery device meets the manufacturer's specifications. They also allow comparison between the various types of systems to see which is most effective. Further review may indicate methods of changing operation or modifying initial design to improve efficiency.

These long-term regular studies often identify a specific problem. Complaints called in or critical alarms indicate other areas that require an intense short-term study. A few applicable points are recorded within a short time frame. These specific studies, which follow, indicate the versatility of the CCMS.

Animal Ventilation Off

Even during cold weather, scheduled fans are stopped at night. There have been fans that do not restart in the morning because they have tripped off on freeze stats. When S-5 (Building #020) at the University of Minnesota was found in an alarm-off condition, it was assumed that the problem was the freeze stat. The fan, however, was scheduled for continuous operation. Review of the preheat air temperature and the fan status showed that the fan did cycle to low temperature and stop, then restart, but then stop even with a high temperature. The problem turned out to be overloading of heaters due to frequent cycling on a resetting freeze stat. The actual problem was a plugged strainer on the preheat coil. After 30 minutes used to review CCMS-gathered data and knowledge of the fan design, corrective action was initiated.

Roof-Top Temperatures

When the University of Minnesota was informed there were to be aerial infrared photographs to indicate areas of heat loss, the mechanical engineering department decided to conduct a ground-based study. One aspect required accurate temperatures to be recorded in several locations on 10 roofs scattered about campus. The readings did not need to be continuous, but needed to at least provide for hourly variations. Using existing CCMS equipment, cards were added to data-gathering panels and sensors were located on the roofs. Two days after the request, 48 roof-top temperature sensors were installed, calibrated and working.

Steam Absorber Start/Stop

As part of the effort to lower energy use, 18 absorption chillers were cycled off at night just before stopping the building fans. They were restarted each morning with the fans. To be successful, this program required an accurate report for the refrigeration shop. It indicated which absorbers did not start or did not come up to full load. CCMS could review critical temperatures and pressures of each absorber as it started and also note effects on the fans and building conditions. Familiarity with the absorber operation is also valuable when there are sudden weather or load changes in a building.

Auditoriums

When an auditorium is unoccupied,

fans, chillers, reheat equipment and radiation equipment are turned off. When the space is scheduled for use, the necessary equipment must be started. This often occurs when there are no shop personnel on campus. Accurate records and review of various temperatures will indicate a problem before it becomes serious. Some corrective actions can be made by the CCMS operator, such as opening the fresh air dampers; or if a mechanic is needed, the correct trade member can be directed to the specific site. Seasonal review of the recorded operation help to improve equipment controls and operating procedures.

Steam Flow to the West Bank

The Minneapolis campus boiler plant generates steam for both the main East Bank campus and the West Bank campus. There are two steam lines to the West Bank providing a loop system. Steammeters are installed in the lines to the West Bank and are connected to the CCMS for instant update of current readings. Whenever there are changes in operation on the West Bank, it can be determined by reviewing these meters. In a week-long study comparing these maters with daily manual readings in the West Bank buildings, an estimate was made of steam line loss.

Control-Point Adjustment (CPA)

One feature is the remote control-point adjustment. The CPA is located on converters to control the supply water temperature, and on absorption chillers to change the chilled water supply temperature. The point to be stressed is that the CPA is an additional manual, but remote, control that affects an existing engineered-to-work-as-designed control network. Once changed, the control system will not work exactly as designed until the CPA is returned to its neutral location.

There are three general areas in which the CPA is most effective. First, the best engineered control system can only be as good as the equipment controlled and the control components. Once installed and initially calibrated, review of actual operational response will indicate possible fine tuning. This can be done using the CPA until proper operation is obtained; then a trade member can be sent to make a final, permanent correction. Second, this fine-tuned control system may fail. As the system begins to deteriorate, a temporary corrective action is possible using the CPA, until personnel are available to make repairs.

The third general area is evident when examining the original design of the controls. By necessity, they could only aim for design loads under average conditions. Seasonal changes between cool, warm or hot weather in the spring or fall can mean a significant difference in the desired operation of a system. Temporary changes can be made for these transition times by using the CPA.

Central Control and Monitoring System Operation

General

The goal of CCMS analysis is to improve either the operation of equipment in the field or to improve the procedural response made to a particular problem. During typical operation, health and comfort are the top priorities to justify running equipment. This is followed by requirements to protect the building, equipment or experiments, with a constant concern for energy conservation. There are flexible features associated with the Honeywell Delta 2000 that are regularly used to implement these improvements. The most straightforward means to avoid spending energy is to leave equipment off.

Fan Schedules

Any type of building equipment may be affected, including high-pressure water pumps, absorption chillers, radiation or reheat pumps, and especially, fans. There are several points of consideration related to the scheduling of any given fan Normal operation standing schedules are determined quarterly to reflect seasonal and occupancy changes. Fans are run only if a space requires ventilation. The CCMS memory feature is programmed to operate 11 different schedules that control about 250 fans. Another feature is the ability to change the entire memory by running in a paper-punched tape. This can be used to change, within ten minutes, from a standard fan schedule to an energy crisis

schedule that is used to cycle fans off and on even while the space is occupied. This tape-reading feature also provides a way of changing alarms from summer high alarms to more appropriate winter low alarms. It also assists in system mode changeover from heating to cooling or stopping fans that are only critical for heat in the winter.

One fan program in the Delta 2000 can contain the address of all fans that are critical for ventilation and that must run 24 hours a day. During periods of normal operation, this program would be idle. If there were a power outage, however, this program could be initiated to restart these critical fans. At present the same procedure in reverse is used to stop fans and reduce steam loads when the heating plant has a shortage or failure. This same procedure is followed to lower the electric demand as may be required.

Alternate Printer

Any alarm may be coded to alarm uniquely at any or all printers that are part of the CCMS. Security and fire systems are not really the responsibility of shop persons beyond maintenance of electrical integrity. These alarms, therefore, are selectively sent to the police so they can directly respond to problems they are uniquely trained to handle. In the future, there will be a feedback acknowledgment so that an alarm that is not answered by the police will be indicated in the CCMS.

Improved Measure of Energy Use

Before any attempt can be made to conserve energy, a complete energy audit is advised. This should be of sufficient detail to document improvements as they relate to changes in operation. On the most part, the fan schedules, which have been discussed, indirectly provide a measure of savings. The horsepower and volume of fresh air is multiplied by the hours off and the appropriate conversion factors to calculate an approximate amount of energy conserved. There is no clear correlation between calculated theoretic savings and actual measurement. In general, the problems include the following:

1. There is a large base-line steam load (about 30 percent) that exists even in mild weather when most systems are off or satisfied. This must be accounted for in line loss and minimum radiation, reheat and domestic hot water.
2. Because of the cyclical nature of outside temperatures and the storage lag caused by the heat capacity of individual buildings, instantaneous changes in CCMS are difficult to detect in the meter readings that are manually recorded daily. While degree-days (daily average below 65°F, 18°C) are a useful guide, the winter steam consumption does not clearly increase until outside air temperatures drop below 58°F (14°C).
3. A very large electrical load, devoted to lighting, cycles with the building use and tends to bury the effects of starting many fans and completely obscures the effect of an individual unit operation.
4. Meters are usually only read monthly. Even for a detailed study, they are read only once a day.
5. An individual meter may not cover one building, but rather portions of several buildings.
6. About one-fifth of the steam used is not metered.

Improvements to these items will improve the accuracy of specific savings for a given action. But, for the present, the broad general summary of all energy programs does show a successful conservation program.

Maintenance

An old warning may still serve well today: "No amount of electronic gadgetry will ever replace having a man in the field." The analysis of data and the establishing of operation limits will mostly interest engineers. It is important to provide systematic maintenance of equipment and a means to organize non-scheduled repair. The use of a computer in a CCMS has been mentioned. The computer is actually any one of three major,

multiperipheral-component, large-memory information systems. These three systems are more complex and sophisticated than the typical minicomputer that might be tacked onto an automation center. They are regularly used as a tool for analysis, as a means to develop new "tape-read" instructions to the Delta 2000 memory, and for the listing of both scheduled and unscheduled maintenance items.

Computerized scheduled maintenance has been used at the University of Minnesota since 1968. Its features are simple, flexible update of equipment and service; continuous improvement of information; and the production of a shop-ticket work order to assure that a required task is done. The different shops (electric, elevator, steam, refrigeration, ventilation, plumbing and fire extinguishers) are the major uses of computerized scheduled maintenance Services may be a simple coded number that matches a piece of equipment to a fully detailed direction, including a form that must be completed and mailed to the environmental health department. Even with organized and documented scheduled service, there are still breakdowns.

Most building systems are on the automation center and many repairs originate as an operational alarm or as an abnormal condition that is noted during a study. Work orders are written on a shop ticket to the proper shop or, if the problem relates to a Delta 2000 component, it is given to the CCMS electronic technicians. In addition, an unscheduled repair may require further review by the engineers. All of these repairs are catalogued by origination date, identification code and area of responsibility for repair. A description of the problem and possible repair is also included. Weekly updates are printed by the computer for progress review. As needed, a listing by equipment code number can be made. This enables a review to see if there is a recurring nuisance that must be further examined.

A different program is designed to manufacture new instructions of fan or pump schedules onto a paper tape. This tape is then read into the Delta 2000 memory. A need to drastically change operation between standard schedules and "energy crisis" schedules dramatizes the usefulness of this program. Within an hour of the policy change, a revised memory stopped noncritical fans on campus in Minneapolis, St. Paul and Duluth. Most fans are listed for a different program that can combine fan schedules, horsepower and flow rates in cubic feet of air per minute. The calculated result is the expected energy savings. The computer is a tool to assist in the organization of information for maintenance, operation and analysis data.

The men in the field have developed several techniques for tracing down an electronic failure in the Delta 2000 components. Often the repair may be as simple as replacing a card. The card itself has components from diodes to integrated circuit chips.

CHAPTER X

MAINTENANCE AND TROUBLESHOOTING

INTRODUCTION

ROUTINE MAINTENANCE

ROUTINE REPAIR

MODIFICATIONS

SYSTEM RELIABILITY

CHAPTER X

MAINTENANCE AND TROUBLESHOOTING

Introduction

It is generally agreed that maintenance and troubleshooting requirements of Central Control and Monitoring Systems (CCMSs) fall into three categories:

- routine maintenance
- routine repair
- modifications

Routine Maintenance

Routine maintenance can best be accomplished by the establishment of checks and balances on the functional use of the total system. For example:

- daily all-point log printouts
- trend logging of a particular unit or point
- printout of a single system
- analysis of alarm or trouble indicators while on-line

Most of the areas or points requiring routine maintenance will present themselves as a result of the above checks as the systems' components come on-line.

Campus mechanics, properly trained, can maintain the average system. The training can be accomplished in various ways.

The manufacturers have training programs available to handle all of the routine maintenance and troubleshooting required. While these programs are very helpful, possibly the best training can be accomplished by a hand-on method on the owner's equipment.

One plant that purchased all the equipment and the services of a manufacturer's installation supervisor had the actual work of installation and wiring done by in-house mechanics. By following this procedure, the mechanics gained very valuable training in the operation and maintenance of the systems. This method also resulted in a substantial saving on the cost of the systems. The manufacturer's representative was not on the job full-time, but was used as a layout man, for checking and testing finished work and to troubleshoot the finished work on a system as it went on-line. The in-house mechanics worked with the manufacturer's representative throughout these procedures. These men are now proving very valuable as maintenance is required.

Routine Repair

While most systems, when completed and after shakedown, require little repair, there are some areas that do require tuning and attention. Some of these are:

- fire alarm systems
- sprinkler systems
- security intrusion detector systems
- humidity controls
- printers
- internal audio systems for maintenance and operations between the central console and data collection panels

Routine maintenance checks usually reveal the problems and they can be handled by in-house mechanics.

When problems occur that are beyond the scope of the physical plant staff, a call to the manufacturer's service departments can help. If that doesn't solve the problem, the manufacturer's service people can be brought in on an on-call basis. A maintenance contract should be established with the manufacturer for emergency repairs of items beyond the capability of the operating crew.

The systems are such that they detect their own troubles for the most part and print out either "trouble" or an alarm to alert an operator to the problem.

Since all of the systems mentioned above are at one central campus and all transmission is on the campus's cable, there are no lease-line problems.

Spare parts inventories can be

established by lists suggested by the manufacturer and from in-house experiences.

Power packs, modular cards, a public address system amplifier, etc. are helpful to have on hand.

Routine inspection and cleaning of all sensors, wiring and components is the greatest deterrent to the need for emergency repairs.

Proving the system with portable testing equipment so that each modular component can be tested and replaced by operating personnel can result in considerable savings.

Modifications

While modifications do not come under the heading of maintenance and troubleshotting, they still have a place in this category in that new problems can present themselves unless the interfacing is understood by the maintenance and repair mechanics.

The modification and updating engineering should be done by the manufacturer and the materials supplier. If in-house installation mechanics are available, they should be used, under a manufacturer's service representative's supervision, to do the work and be kept up-to-date on maintenance and repair.

All software modifications could be performed on an in-house basis, if the manufacturer is prepared to disclose his coding techniques. This should be discussed when the system is purchased.

System Reliability

System reliability guarantees should be made part of the purchase agreement. Components should be guaranteed for a period of one year. The system engineering and overall system performance should be guaranteed for a period of five years.

CHAPTER XI

ADAPTING CENTRAL CONTROL AND MONITORING SYSTEMS TO ENERGY MANAGEMENT

INTRODUCTION

ENERGY MANAGEMENT SOFTWARE
- Start/Stop
- Load-Rotation Programs
- Load-Shedding Program
- Reset Programs
- Optimization Programs
- Power Factor Improvement Program
- Load and Performance Profiles Program
- Maintenance Management Program
- Lighting Control Program

APPENDIX

CHAPTER XI

ADAPTING CENTRAL CONTROL AND MONITORING SYSTEMS TO ENERGY MANAGEMENT

Introduction

"No other single factor has had more influence in creating the building automation and energy management stampede than the Arab oil embargo and the quadrupled cost of oil." This quote is from Chapter I and is repeated here to emphasize why Central Control and Monitoring Systems (CCMSs) are receiving special attention. It is a proven fact that the CCMS saves energy. It does this in many different ways, the sum total of which is nothing short of dramatic. The computer-based CCMS utilizes its software to perform the numerous energy management routines. Software programs were discussed in general terms in Chapter III. In this chapter, these software energy management programs will be examined in further detail.

Energy Management Software

Start/Stop

This is the simplest type of program; yet, with modifications, it becomes the most effective energy saver, particularly when used in conjunction with other programs and routines.

In its most simple form, a start/stop program is arranged to start and stop equipment according to a predetermined schedule. The program can also open and close dampers, turn lights on and off, and reset temperatures for occupied and unoccupied situations.

In this program, manual override can be provided with automatic reversion to program control at the end of an occupied or unoccupied period.

Interface with other programs allows the basic program to be overridden and equipment turned on and off to handle changing situations.

Start sequences can be arranged in a "cascade" manner to avoid simultaneous starting of many pieces of equipment, thereby avoiding the cumulative effect of in-rush currents that cause a high peak electrical demand.

It is important to set forth the requirements of the desired number of controlled motors and the desired cycling schedule. Certain start/stop packages offered have severe limitations in regard to the number of cycled devices and the number of start/stops per time period. In such cases, additional software programs, specifically designed for load rotation, are required.

Load-Rotation Programs

This program may be a part of a load-shedding program or may be an independent software package, depending upon the manufacturer's format. One manufacturer refers to it as "duty cycling." Under this program the CCMS cycles selected electrical loads on and off during the day, reducing energy consumption. Equipment is shut off for short periods, permitting temperature conditions to drift slightly. Cycled loads are rotated throughout the day. Duration and frequency of the off cycles can be assigned individually to each connected load. When space temperatures remain satisfied, the equipment remains off for a longer period. Conversely, when the temperature drift becomes unacceptable, the "off" period is shortened.

Load-Shedding Program

This program is used in conjunction with start-stop and load rotation programs to override normal operation and to turn off equipment as a predetermined peak load value is approached. In its simplest form, the program would shut down selected equipment according to the measurement of peak load. The program can be modified to include a rolling-priority feature. This feature allows equipment to be shut down on an assigned priority basis for a predetermined period of time

after which it is returned to service and a lower priority piece of equipment turned off. The rolling priority would only be activated when a predetermined peak load value is approached, and the equipment turned off would be limited to that necessary to make certain that the load remains below a given level.

Interface of this program with an electrical profile routine allows development of a continuous profile of electrical demand and calculation of predicted load in the immediate future. This predicted load would then be used to initiate the rolling priority sequence in order to alter the slope of the prediction curve.

The current maximum peak load experienced in the previous billing periods would also be held in memory and used as the criterion for load shedding. This value could be constantly modified based on monitored information.

It is interesting to note the number of manufacturers who are now producing load-shedding, demand-limiting equipment. In addition to the computerized CCMS companies, electrical hardware manufacturers such as Allen-Bradley and Square-D offer a broad line of equipment for this purpose. The bottom of the line is usually a configuration of time clocks with an unsophisticated "program." The top of the line is a programmable micro- or minicomputer capable of forecasting and continuously resetting the limiting levels that reduce consumption as well as demand.

Reset Programs

These programs are designed to reset the control points of thermostats and pressure controllers, and to interface with with load shedding and optimizing programs. In place of, or in addition to, turning off equipment for load shedding and energy conservation, loads can be trimmed, i.e., if a peak load is approaching, space conditions can be reset to reduce cooling or heating loads; outdoor air dampers can also be reset in this type of program. See also the Supply Air Reset Optimization program described below.

Optimization Programs

These programs tend to be more sophisticated than the others so far described, requiring interface with an arithmetic routine to allow optimum settings to be calculated. The optimizing program interfaces with the start/stop program, load-shedding program and reset program to modify operation of equipment. Most of the following programs are available from the major CCMS manufacturers. Some of the programs are available only from certain companies or must be written specifically for the project in question.

1. Optimum start: This program can delay the start of primary equipment, e.g. chiller, boilers and individual air-handling units, until the last possible moment to provide a comfortable environment in the space at the time of occupancy. This program is designed to condition the major mass in the space before occupancy to provide proper occupant comfort. Conditioning the space involves the important comfort aspects of wall and furniture temperatures as well as proper air temperatures.

   Start times are based on the warm-up and pull-down load created by the mass of the space and to a minor extent instantaneous external weather conditions that occur during the warm-up or pull-down period.

   Based on the optimal times calculated, equipment is started automatically or operator instructions will be printed for manual stop/start operation. Local codes must always be considered.

   The greatest savings provided by delaying the start-up of a warm-up or cool-down cycle is the savings in energy required to operate the primary equipment. This program assumes the option to run the equipment at maximum capacity even to the extent of overheating or subcooling, if this saves more in primary equipment operating costs than it wastes in heat loss.

2. Outdoor air (enthalpy): When the outdoor air temperature is below the desired leaving air temperature of the cooling coil, the program will call for "free cooling." By permitting the local loop to

control the mixed air temperature at the desired leaving air temperature of the cooling coil, full advantage is taken of the free cool air available.

When the outdoor temperature is above the desired leaving air temperature of the cooling coil, the enthalpy program will perform total heat calculations. By calculating outdoor and return air enthalpies, the program can decide system usage of outdoor air, return air or a mixture of the two.

3. Supply air reset: On fixed volume reheat systems such as all-air terminal reheat systems and on double duct systems, the supply air temperature for cooling is usually fixed. Decreased cooling loads on the system are reflected by increased reheat (steam or water coils or air from the hot deck) with no change in the supply air temperature.

   For terminal reheat systems, the supply air reset program receives an input indication of the reduced cooling load. Supply air temperature is then raised according to the amount of cooling load reduction. This reduces the amount of mechanical cooling used and also the amount of reheat required at the space. Supply air temperatures are only raised within the limits of the humidity requirements as established by the comfort chart and as controlled by return air controller override.

   For double duct systems, the supply air reset program receives both high (cooling) and low (heating) signals from the representative zones.

   The lowest heating signal is used to control the hot deck at a temperature just high enough to satisfy the space calling for full heating. The highest cooling signal is used to control the cold deck at a temperature just low enough to satisfy the space calling for full cooling. The supply air reset program can reduce hot deck temperature in lieu of increasing cold deck temperature if that is more economical.

   Because of the large number of mixing boxes in a double duct system, supply air temperature optimization must be accomplished on a selected zone or area basis. The following guidelines apply:

   a. Select zones that represent worst case loads for the system.
   b. Include as many exterior corner zones as possible.
   c. Include representative exterior middle zones and interior zones.
   d. Spring ranges of mixing boxes in the selected zones should be identical.

   To reduce the average relative humidity within the building, the return air dew point will override and readjust the cold deck temperature whenever return air relative humidity exceeds a selected high limit. When the cold deck temperature is at a minimum value, the program can raise the hot deck temperature to force the zone terminal units to use more cool, dehumidified air.

   The multizone system is another form of the double duct system with similar requirements and controls.

4. Chiller plant: The chiller plant optimization program applies to series or parallel piped, absorption or centrifugal chillers. The program assumes that each chiller is provided with a means of reducing its capacity (inlet vanes, variable steam supply, etc.) and that a curve can be provided that approximates the input/output characteristics. Multiple-cell cooling towers, with fans that can be started and stopped or varied from high to low speed, are also included. The program described is based on centrifugal chillers; however, absorption chillers can be handled in the same manner, although the inputs may be sensed differently.

   The discharge water of the local-loop control-sensing common chiller controls the chillers'

capacity at all times. All operating chillers are loaded equally. The set point of this controller is determined by the program in order to:

a. Maintain the chiller discharge water temperature at the highest allowable value to maintain maximum chiller efficiency. This requires monitoring of system parameters to determine maximum cooling requirements.
b. Readjust the local loop controller whenever this temperature deviates from the desired value. This eliminates the drift normally associated with proportional controllers.

Each chiller load (inlet and outlet temperatures and flow) is constantly monitored and individual chiller loads are combined to determine the total load on the system. The operating characteristics obtained from the equipment manufacturer, entered into the program, assist in determining the number of chillers that should be operating and the load on each chiller to produce the lowest kilowatt (kw) per ton operating characteristic of the various combinations. Sensing the power input of each chiller (i.e., pump and chiller motors), the program also calculates the efficiency of each chiller and uses this information to update the manufacturer's operating characteristics. The efficiency and a history of run time on each chiller determines the chiller operating sequence for maximum efficiency and equal wear. The program also prevents starting the compressor more frequently than the manufacturer recommends.

Power Factor Improvement Program

This program provides continuous monitoring of the power factor for individual buildings on the entire complex, as appropriate. When the power factor drops below a reset limit, the system automatically switches in a bank of capacitors to provide power factor correction. If the power factor is still below the desired value, the system will automatically pull in the second and succeeding banks until the desired correction is achieved.

Load and Performance Profiles Program

This program is not a standard software package but is useful for building management, cost reduction analysis and long-range strategy planning. The most common variables that are integrated include daily and monthly cooling and heating loads, daily and monthly kilowatt-hours (kwh), kilowatt demand and total electricity, gas, oil, steam or other prime energy costs.

Maintenance Management Program

Maintenance management programs are "canned" or written specially for a particular project. They are intended to put maintenance on an efficient basis concerning primarily preventive maintenance as opposed to emergency procedures. The programs typically consist of the following elements:

- building inventory
- equipment inventory
- maintenance task information
- maintenance schedule
- work order generation
- maintenance cost information

Maintenance management programs are a notorious "memory hog." Only those institutions with many buildings and large computer capacity can cost-effectively utilize a maintenance management program. Few of the major CMS manufacturers offer a "canned" program. A program offered by the Johnson Controls is included in the Appendix to Chapter XI.

Lighting Control Program

This program can be effective in reducing lighting kilowatt-hours, providing it is utilized in new construction or remodeling programs. This program can ensure that lighting is on only when actually required. Lighting schedules may be established for the entire building or portions of the buildings as may be required for departmental work-hour variations. Computer program override is available through the keyboard to accommodate unscheduled overtime hours.

APPENDIX TO CHAPTER XI

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM

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COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM

The Johnson Computerized Maintenance Management System consists of special software packages and printed forms that combine to provide a comprehensive system of maintenance management that will ensure peak operation and efficiency from the various mechanical and electrical systems. Following is a detailed description of this system.

Input File

Special forms are provided to generate an input file which consists of an inventory of all tasks to be performed on the mechanical and electrical equipment in each building. The input file includes the following information:

Building Inventory Information

1. List of all buildings and major maintenance areas

Equipment Inventory Information

1. System/component location or maintenance area
2. System component inventory (motor, pump, etc.)

Task Maintenance Information

1. Identification of tasks with each component
2. Identification of tasks with preventive and breakdown categories
3. Task description--4 lines with 26 alphanumeric characters each
4. Skill code description--4 mnemonic digits and 18 alphanumeric characters
5. Material code description--26 alphanumeric characters
6. Tool code description--26 alphanumeric characters
7. Contract code description--26 alphanumeric characters
8. Task initiator--calendar time, equipment running time, or actual performance parameter. The time between maintenance tasks is defined in terms of the above (days, hours or unit).
9. Extenuating message--26 alphanumeric characters--use as many lines as required.

Maintenance Programs

Special software packages are provided to implement the following maintenance programs.

Maintenance Scheduling and Work Order Program

The maintenance scheduling and work-order program schedules all preventive maintenance tasks with hard-copy work orders for each skill/trade person. Hard-copy work orders are generated automatically on the day such tasks are due or by operator request if longer periods are required.

Preventive maintenance tasks are scheduled on the basis of calendar time, equipment run time and assigned equipment performance index. Any maintenance task previously scheduled but not complete is reincluded in the program for work-order scheduling.

Each work order is issued on hard copy for each skill/trade person and includes the following information:

1. Date and time of issue of the work order
2. Customer-implemented skill/trade code (four numeric digits) and English description (up to 18 characters) identification of the person to whom the work order is issued
3. Listing of all the tasks to be performed
4. The task listing is organized in two level groupings, so that all the tasks within a building are shown grouped together in the first level and tasks within a building area are grouped together at the second level.
5. Each task is listed with task location, appropriate task description, material and tool codes required and the parameter (calendar time, run time or performance index) which initiated that particular task.
6. Each task description has up to four lines of printout, with up to 26 characteris per line. The description is alphanumeric and is assigned by the owner.
7. Each task is assigned a separate work order number and this is printed out.
8. Each work order is provided with sufficient space to allow for reporting: Done/Not Done; Actual Time Required; Actual Material Used.
9. Any task which has been rescheduled is identified by an asterisk or any substitute special character depicting the fact that said task is overdue.
10. Each work order contains a detachable portion specifying the actual average time and the material required to perform each task.
11. The detachable portion of the work order is properly identified for later matchup with the work order issued to the worker.
12. Each work order includes a summary printout of the material(s) and tool(s) required to accomplish the scheduled maintenance tasks.

Maintenance Forecasting Program

The maintenance forecasting program provides management personnel with the necessary reports required to forecast manpower requirements for any specific day over a selectable period of one year. Inequalities are capable of correction through reassignment of maintenance tasks.

Forecast reports are of two types and based on the updated current data in the maintenance software file.

1. Time distribution report: The operator selects the time period for which he is concerned. The program prints out each day of the selected time period with its respective totalized time required to complete all the tasks that are coming due on that day.

2. Task distribution report: The operator selects any skill/trade and a future date. The program prints out all scheduled tasks, their locations, their instructions and the actual time required for completion of each. Each task also includes accumulating time for itself and all previously listed tasks.

Maintenance Action Program

The maintenance action program accepts all information regarding maintenance actions performed (unscheduled, preventive scheduled and breakdown) within the building complex and updates the data files in the maintenance software package.

Input data for this program is executed on an exception basis only. Maintenance tasks completed within the time and with the materials allocated do not require an input into the system.

Input data for unscheduled or overdue maintenance tasks or those which exceed the work order limits are via keyboard entry and include:

1. task performed
2. skill/trade person who performed task
3. actual time required to complete task
4. actual material used to complete task

Upon receiving this information the program updates the task information, clears the completed work orders, updates actual labor and material used, updates cost totals and updates the task(s) not completed.

Cost Summary Program

The cost summary program provides management personnel with reports showing the direct cost of maintenance operation.

The cost summary report is based on actual time and material utilized for each task and is organized by building, system, skill code and task code to show running totals for labor and material.

Cost summary reports are itemized as to cost for preventive maintenance, preventive breakdown, breakdown and outside contract.

Cost summary reports are provided on a "month-to-date" and "year-to-date" basis. The following cost summary reports are provided:

1. the entire building complex
2. any given building within the complex
3. any given system within a building
4. any given task category for the entire building complex
5. any given task category for a building within the complex
6. any task category for a given system within a building
7. by skill/trade category for the entire building complex
8. by skill/trade category for any given building within the complex
9. By skill/trade category for any given system within a building
10. by skill code category and task code category for the entire building complex
11. by skill code category and task code category for a given building in the complex.
12. by skill code category and task code category for a given system within a building

*Equipment Repair History Program

This program operates in conjunction with the maintenance active program and provides the operator with the breakdown history and preventive maintenance history for each item of equipment.

Breakdown history includes:

1. number of times
2. material cost
3. labor cost
4. outside contract costs

Preventive maintenance history consists of the cumulative material and labor costs.

*Building Maintenance Inventory Program

This program provides management with a perpetual inventory system based on output from the maintenance action program. The inventory program files includes material/part codes for all items listed in the maintenance management program.

Maintenance inventory data are provided on paper tape formatted in ASCII code. This can be used to maintain the inventory by printing requisitions or purchase orders.

Operator Updates and Reassignments

In order for the operator to keep the maintenance program current, the following file updates, reassignments and changes are provided.

Estimated Time Update

The estimated time update program allows an operator to change the estimated time required to perform a task.

Skill/Trade Code Update

The productivity time originally assigned to each skill/trade is capable of being changed by the operator.

Material Code Update

The material code update program allows the operator to change the material versus code assignments and the material quantity needed per task.

Extenuating Message Update

The operator is able to change the content of the extenuating message for tools, materials, tasks and/or skill trades by reassignment of the program file.

*Future programs; availability to be announced.

Calendar Time Update

Tasks initiated by calendar time are capable of being rescheduled to different days and the time between task assignments altered on a task-by-task basis.

Task-Initiate Reassignment

The task-initiate reassignment program allows the operator to reassign tasks originated by a certain task-initiator category to another initiator category. Task-initiator categories include calendar, performance and run time. Tasks initiated by performance input have operational limits in software that are easily altered by an authorized operator.

Task Update

The operator is able to update tool, material, skill trade and/or contract assignments on a task-by-task basis.

Task Status Change

Due to seasonal changes, extensive equipment repairs, facility modifications, etc., the operator is able to place tasks on a task-by-task basis in either an active or inactive status. Inactive tasks are removed from the maintenance scheduling and work order program.

Management Reports

The Johnson Maintenance Management System includes the following management reports. In addition, reports for inactive material codes, tasks not done and extenuating messages are included.

File Report

The file report provides all tasks information to the operator on a system basis. The report includes:

1. building and system names and codes
2. task identification
3. task status, i.e., active versus inactive
4. start day and overdue time period for tasks
5. actual accumulated hours for run-time initiated tasks
6. maintenance interval time in hours or days for run time
7. actual accumulated days for calendar-time initiated tasks
8. maintenance interval time in days for calendar-time initiated tasks
9. codes for skill, task, material, tools and outside contract assignments
10. alphanumeric description of each maintenance task

Skill/Trade Report

The skill/trade report provides all skill/trade information to the operator on a skill/trade or man-by-man basis. The report includes:

1. task status (active versus inactive)
2. code for the man or trade

3. his identifying alphanumeric title
4. present hourly dollar and cent pay rate
5. number of cumulative hours worked by each code category
6. total cost for each code category
7. productivity-per-day ratio for each man or trade

Maintenance Task File Report

The maintenance task file report provides task information to the operator. It includes:

1. task codes
2. alphanumeric task description
3. message location address
4. average actual versus estimated time
5. material usages

Maintenance Material File Report

The maintenance material file report provides the operator with the following information:

1. material status (active versus inactive)
2. material codes
3. corresponding material alphanumeric instructions
4. present cost per material unit
5. message location address
6. cumulative yearly actual usage and cost for each material item

Maintenance Tool File Report

The maintenance tool file report provides the operator with the following information:

1. tool status (active versus inactive)
2. tool codes
3. alphanumeric tool instructions
4. message location address

Inactive Task File Report

The inactive task file report provides the operator, on a building and system basis, the inactive tasks within the complex. Each task listed includes:

1. task identification
2. alphanumeric description
3. all codes for skill, task, material and tools
4. outside contract maintenance clearly associated with each task instruction

Overdue Task Report

The overdue task report relays to the operator those tasks which are incomplete or not reported and which should have been completed. Overdue periods assigned are printed to coincide with the specific task instruction.

Overdue tasks appear on the report for two consecutive overdue periods and tasks are identified as to whether they are overdue by one or two period intervals. Tasks are printed out on a building, system and location basis with alphanumeric identification.

APPENDIX A

PRELIMINARY ANALYSIS OF ENERGY CONSERVATION ECONOMICS FOR THE UNIVERSITY OF MARYLAND (College Park Campus)

Richard P. Mueller & Associates, Inc.

December 1973

SUBMITTED TO: University of Maryland
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PRELIMINARY ANALYSIS OF ENERGY CONSERVATION ECONOMICS FOR THE UNIVERSITY OF MARYLAND, COLLEGE PARK CAMPUS

Introduction

The cost of energy in all contemporary forms (utilizing electricity, fuel oil and natural gas) is rising substantially and all indicators are for the price situation to worsen with time--not be relieved. Average cost inflation rates (5 to 6 percent annually) have shown a recent trend toward 10 to 12 percent. Rate increases of 200 to 300 percent during the next five years are now considered probable (equivalent to 15 and 25 percent annual compounded increases, respectively).

Therefore, it is prudent that high energy consumers minimize their energy consumption. This will not only decrease their total projected operating costs, but, in a more altruistic sense, help conserve the nation's and world's unrenewable energy reserves and improve our balance of payments position. Another important aspect to be considered is that increased quantities of certain energy sources (e.g. gas, oil) may not be available at <u>any</u> price in the near future.

Important questions to be answered are:

1. What are the projected additional costs for energy (i.e., over today's billing rate)?

2. How can these costs be reduced?

The analysis presented in this report is primarily based upon University of Maryland, College Park campus, historical records of energy use and costs from 1969 to the present. The results are therefore directly applicable to the College Park campus. Historical fuel oil cost was obtained from an independent source.

The results presented in this report allow cost calculations to be made. Savings resulting from reduced consumption can be applied in whole or in part to energy conservation measures. These data can be used to determine investment monies that can be paid back through reduced energy consumption in a reasonable period of time. In addition to saving money, these facility improvements will ensure better physical plant operation and accrue additional savings in manpower and maintenance costs.

Analysis

The cost of energy in the United States had been decreasing in terms of dollars per watt-hour until the early 1970s. Many factors, including decreasing supply, general inflation and lower conservation efficiencies have acted to produce a rapid increase in energy costs since about 1969. Since then, the cost of energy, in general, has increased substantially. Electrical energy has increased at an average rate of 5 percent to 6 percent per annum. (See Fig. A-1.) The cost of fuel oil has increased at a steeper rate in a shorter period. (See Fig. A-2.) Present rates appear to indicate a 10 to 15 percent annual increase rate, although with such unpredictable occurrences as the current Arab oil boycott, an annual increase of 25 percent for the next

five years appears possible. This cost increase is coupled to a government-mandated fuel allocation program. The additional costs of such increases can be scoped as follows:

Assumption of a Short-Term Exponential Energy Inflation Cost Rate

The cost of energy appears to increase at an exponential rate expressed by:

$$C = Co\ e^{rt} \qquad (1)$$

C = Cost (i.e., dollars/kilowatt-hour, etc.)

Co = Base cost

r = Rate of increase coefficient

t = Time (years)

In fact, the coefficient "r" is itself increasing (from about .05 to .1 within the last two years). The actual cost of such increases can be determined by integrating equation (1):

$$D = \int_{t_0}^{t_f} C = \int_{t_0}^{t_f} Co\ e^{rt} = \frac{Co}{r}\left[e^{rt_f} - e^{rt_0}\right] \qquad (2)$$

Where:

D = Total Cost in $(t_f - t_0)$ years

t_f = final year of evaluation

t_0 = initial year of evaluation

Equation (2) is correct only if the rate coefficient is constant. Present indications are that it is not. However, by assuming several constant "r" values (conservative, nominal and maximum) the boundaries of the total costs can be determined.

This analysis assumes a conservative value of 5 percent. An energy cost increase by a factor of two or three in the next five years if equivalent to 15 percent and 25 percent rate increases per annum, respectively. These three values (5 percent, 15 percent and 25 percent per annum) are selected for cost evaluations during the five-year period starting in 1974. The result of such increases (assuming no change in demand) is shown in Fig. A-3.

As energy costs increase, the potential for saving through energy conservation measures increases. Conversely, a greater sum can be spent in order to obtain a certain percentage economy. The total savings accrued by specified economy values as a function of the average energy inflation rate are presented in Fig. A-4, A-5 and A-6 for electricity, fuel oil and natural gas, respectively, and in Fig. A-7 in toto. These dollars (due to energy conserving measures) could be invested to reduce overall energy costs without increasing physical plant operating costs.

The next question to be assessed is, "What is a realistic target in terms of demand reduction?" A conservative approach is to assume an historical inflation rate of 5 percent (it can't be less) and a moderate reduction in demand of 5 percent overall. This results in a minimum potential savings of $634,000 over the projected cost for energy at current demand. An inflation rate of 25 percent per annum and a 20 percent overall reduction in energy usage appears to be the maximum attainable change over current conditions and results in a potential $4 million savings.

The lower value ($634,000 for a 5 percent inflation rate and 5 percent demand reduction) presents the "minimum risk" (and minimum return) alternative and the upper value the "maximum risk" (and maximum return) alternative. A middle-of-the-road approach is to assume a moderate energy cost inflation rate (i.e., 10 to 15 percent per year) and a moderate demand reduction (10 to 15 percent). In this case, a cost saving of $1.4 to $2.3 million appears attainable.

In general, it is expected that a 5 to 10 percent reduction in energy demand can be obtained by institutions at minimum cost for promulgation and enforcement. Savings of 10 to 15 percent should be possible with a substantially greater cost for enforcement and implementation. Savings greater than 15 percent should be possible, but only by incorporating expensive measures including system modification and the addition of automatic control system equipment. It is not expected that demand increases greater than 20 percent will occur in the short term. Further decreases in utility demand are possible by use of alternate power sources such as solar absorbers or wind generators. However, none of these sources are likely to impact upon contemporary systems before 1979.

The preceding analyses are based upon the assumption that energy demand will remain constant in the near-term future. This is contrary to experience. Historically, the overall energy consumption rate at the University of Maryland, College Park campus, has increased at an annual rate of more than 10 percent for the last four years. A 5 percent overall demand reduction therefore implies a 15 percent net change from the present energy growth pattern.

In conclusion, the results of this analysis indicate that energy use optimization will result in tangible and substantial dollar savings that will increase with time. These measures are a sound investment for the University.

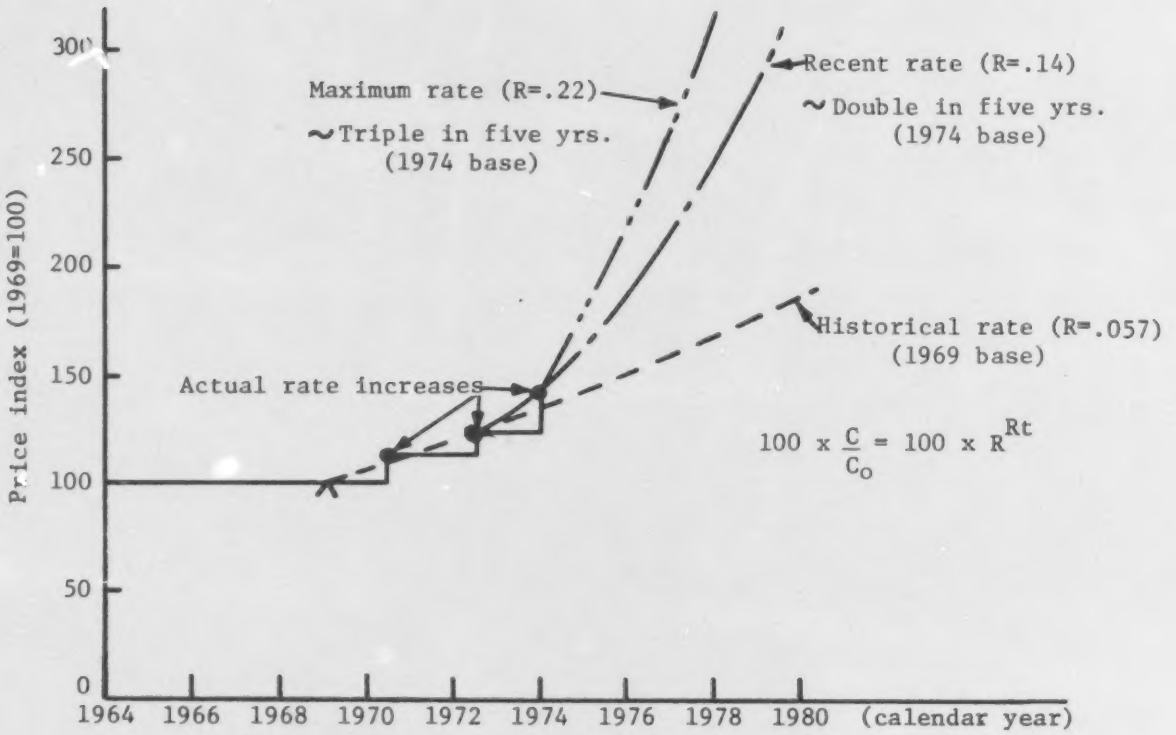

Fig. A-1--Electric power price index

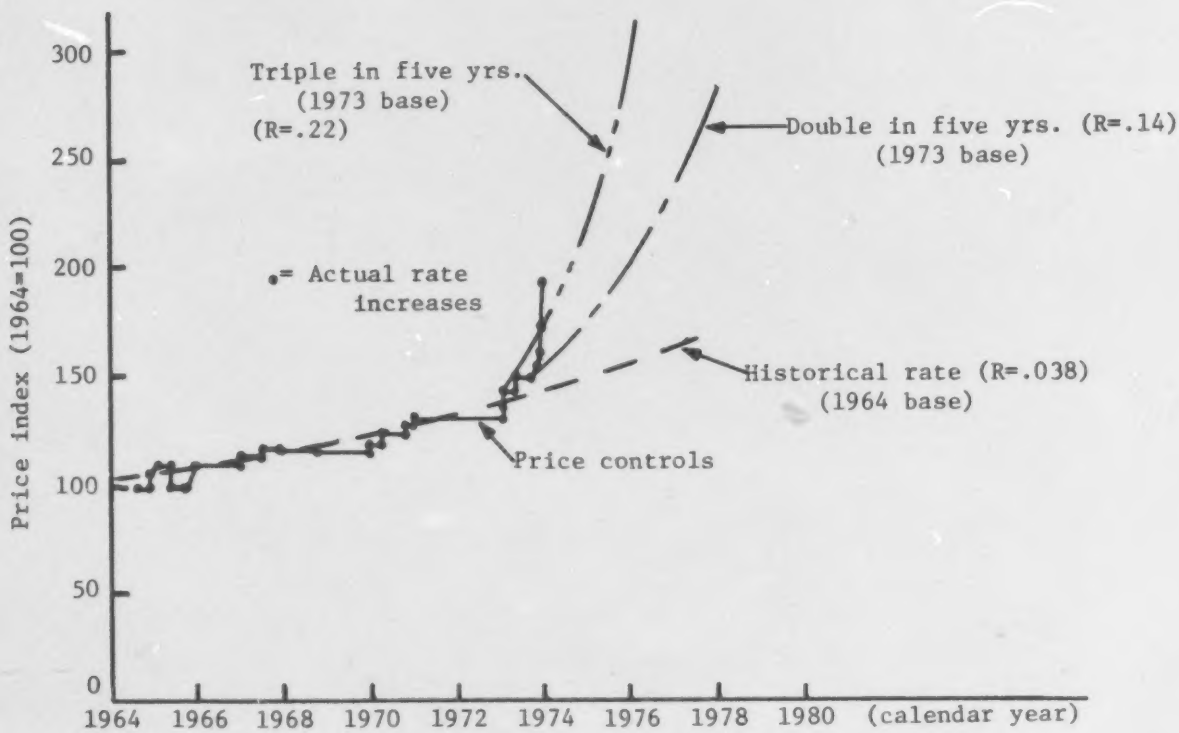

Fig. A-2--Residential fuel oil (#2) price index

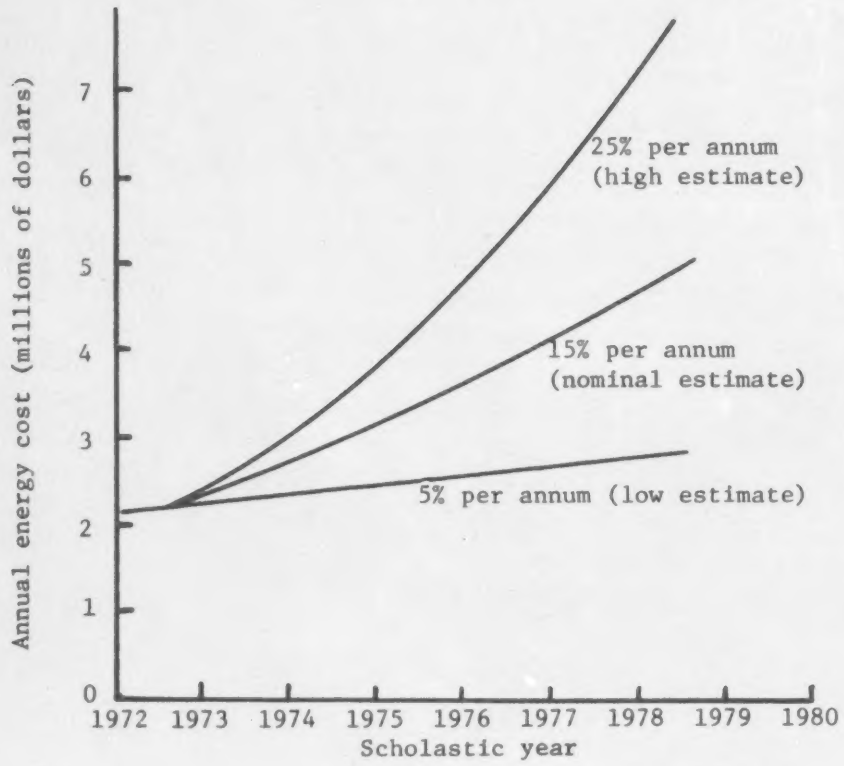

Fig. A-3--Annual energy cost, assuming no change in demand, per academic year

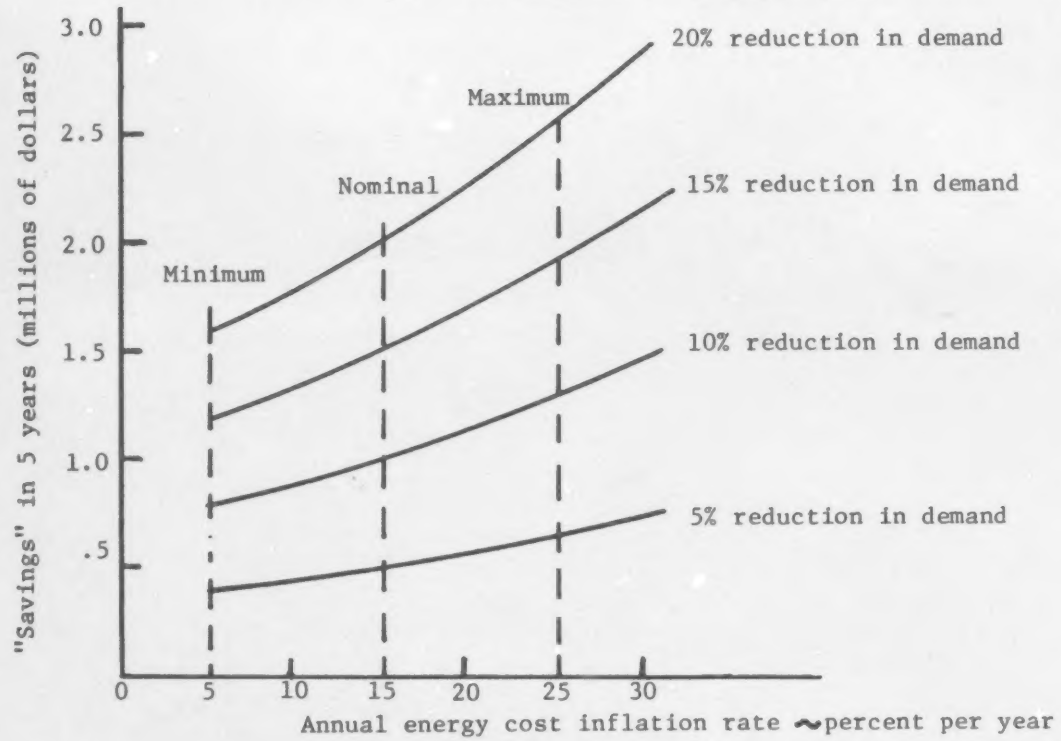

Fig. A-4--Electric power cost savings vs inflation rate and demand reduction

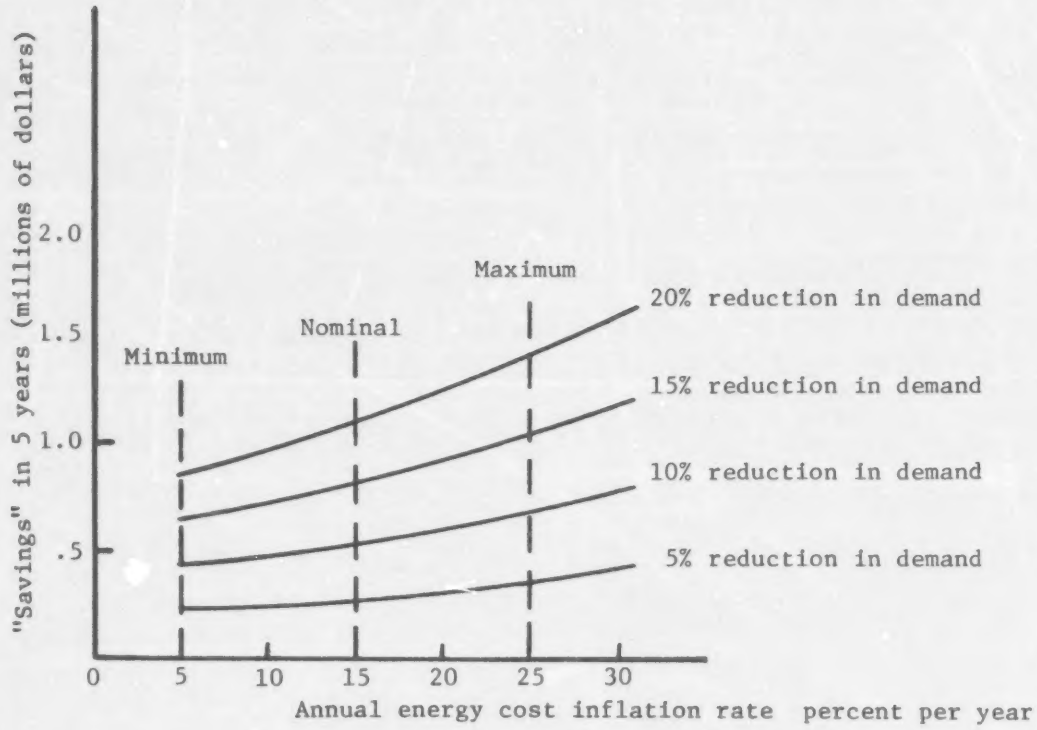

Fig. A-5--Fuel and freight cost savings vs inflation rate and demand reduction

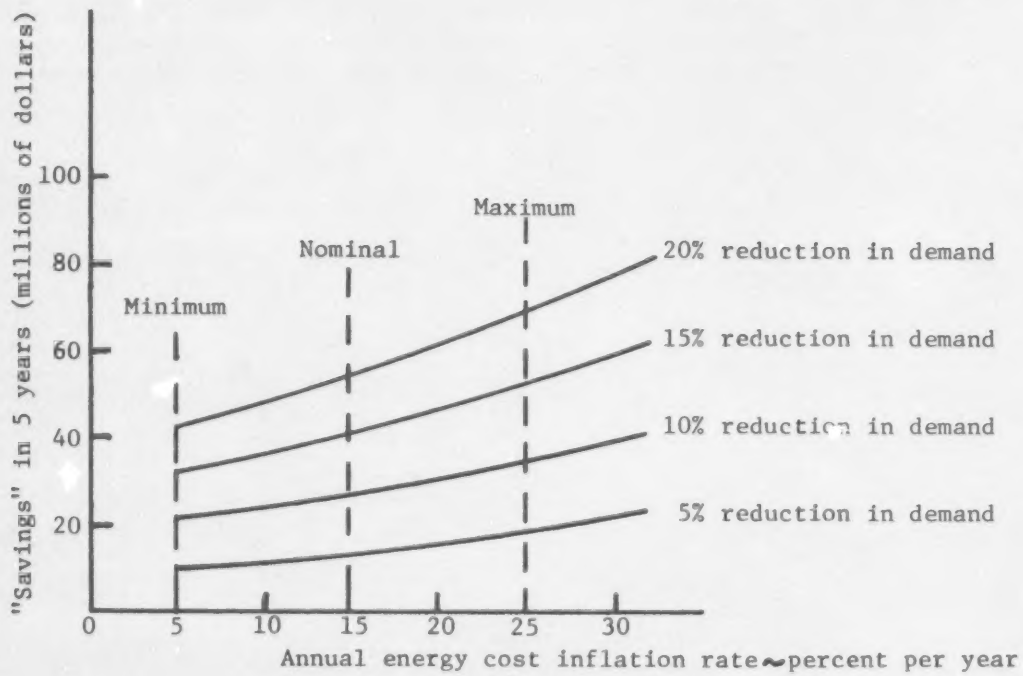

Fig. A-6--Gas cost savings vs inflation rate and demand reduction

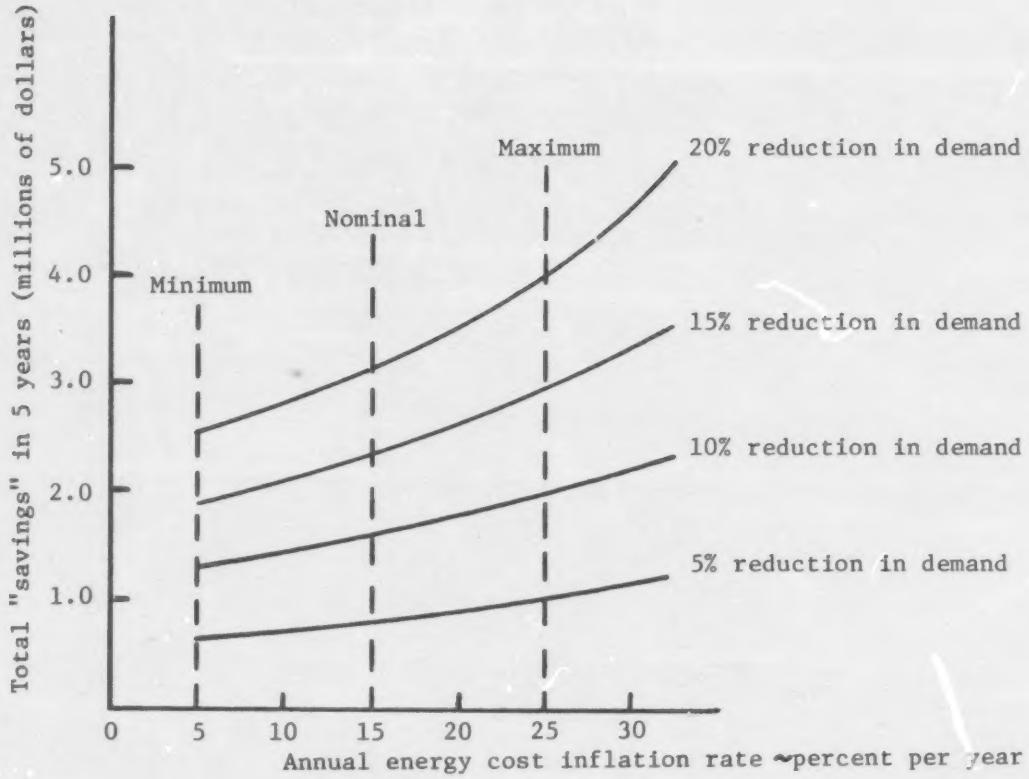

Fig. A-7--Total energy cost savings vs inflation rate and demand reduction

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Address	a coded representation to indicate the destination of data or of their originating terminal
Alarm	a warning signal indicating the condition is not normal and not within operating limits
Alphanumeric	characters which are either letters of the alphabet, numerals or special symbols
American Standard Code for Information Interchange (ASCII)	an eight-level code for data transfer adopted by the American Standards Association to achieve compatibility between data devices
Analog	the representation of numerical quantities by means of physical variables of continuous function
Analog to Digital Converter (A to D)	a device which can convert a variable voltage signal into a series of coded voltage pulses
Annunciator	a device to bring to the attention of the operator the condition or status of a point
Binary Code	a unique signal consisting of a series of "zeros" and "ones" in some predetermined sequence
Bit	binary digit
Cable	assembly of one or more insulated electrical conductors within an enveloping protective sheath
Cathode Ray Tube (CRT)	video screen, like a television screen, used to display data and information
Cathode Ray Tube Terminal (CRT)	cathode ray tube with alphanumeric typewriter keyboard that can be used to issue commands or instructions to the system
Central Control and Monitoring System (CCMS)	a system for controlling and monitoring remote mechanical, electrical, utility and life-safety building systems from a central location
Central Console	The central operating console includes office desk furniture, arranged to receive the various modules; or, it can be factory-formed steel furniture with inlet flush instrumentation. The modular furniture approach is normally cheaper and more flexible.
Central Processing Unit (CPU)	the section of a computer that contains the main-core storage, arithmetic units and registers that control and perform the execution of instructions
Coax	special constructed single or multiconductor cable having specific electrical characteristics
Command Keyboard	a keyboard, similar to a typewriter, with ASCII or other characters, which allows the operator to input instructions to the system.

Computer	a device capable of solving problems by accepting data, performing prescribed operations on the data and supplying the results of these operations
Control Point Adjustment (CPA)	a method by which the analog set point of a controller is changed to a new value
Core Memory	the commonly used main computer memory for storage of programs and data
Data	a collection of facts, numeric and alphabetical characters, which is processed by or produced by a computer
Data Collection Panel (DCP)	panels housing the remote terminals and all the necessary electronics and electromechanical devices. These are pre-engineered, prewired, and factory tested prior to delivery to the job site. Referred to by different names by different manufacturers as follows: Barber-Colman--Data Acquisition Panel (DAP); Honeywell--Data Gathering Panels (DGP); Johnson Controls--Loop Remote (LR); Powers Regulator--Field Cabinet (FC); and Robertshaw--Data Concentration Terminal (DCT).
Digital	data in the form of discrete digits representing a finite quantity or condition
Digital Transmission	the transmission of a signal by means of a high frequency pulse, normally in a binary code of ones or zeros represented by plus or minus DC voltages or plus or zero DC voltages
Disc	a nonprogrammable bulk storage, random access memory consisting of magnetizable coating on one or both faces of a coated thin circular plate
Discrete	synonymous with digital
Error Detection	the formatting of transmitted data so that the spurious noise spikes or magnetically induced voltages will be detected. The existence of these errors will be enunciated at the central console.
Field Point Boards (Point Modules)	printed circuits on 1/16-inch thick glass epoxy, with gold over nickel connecting tabs and containing circuit logic
Format	the predetermined arrangement of field, lines, page numbers, functions and similar characters
Graphics	the representation of a portion of the system by means of diagrams or analogs. Graphics are usually engraved, plastic and colored materials.
Hardware	the physical and material portions of the system, including the magnetic, electrical, electronic and mechanical devices or components of a system or computer
Hardwire	pertaining to wiring systems in which conductor pairs for each signal or point are run to the PECC or TRP. Not multiplexed.

Human Engineering	interfacing the human into the system, considering such factors as fatigue, judgment, reaction time, human memory, availability and replacement
Indication	a visual display of status
Information Display	the means by which the system communicates information visually to the operator (human engineering)
Input	a signal entering a device
Input Device	a sensor or other device which inputs signals into the CCMS
Input/Output Device (I/O)	a device utilized to communicate and interact with the CPU, for example CRT, typewriter and printer
Interface	a common boundary between automatic data processing systems or parts of a single system
Line Printer	a printer device that can simultaneously print several character graphics on hard copy
Memory	a device or media used to store information in forms that can be understood by the computer hardware
Microcomputer	a small computer utilizing microprocessors
Minicomputer	a small computer usually incorporating miniaturization of hardware circuits to minimize size
Monitoring	a term to describe what the central processor does for a living
Motor Control Center (MCC)	enclosure for accommodating motor starters and related controls and accessories
Multiplex, Matrix	transmission of multiple-coded signals over a group of conductors which are arranged by rows and columns to form a matrix
Multiplex, Time-shared	digital transmission of multiple signals over the same path by using different time intervals for each transmission
Operator Communication Capability (OCC)	the various ways and commands the operator uses to communicate with the system (human engineering)
Operator's Console	an input/output device or group of devices used to communicate with the control system
Optimizing	improving the performance of an electromechanical process through the logic of a central processor or operator action
Output Device	a remote output device providing a means of converting a command signal into an operational function
Parity Checking	the addition of a "bit" to each "word" so that the sum of the "odd bits" is always constant. The machine reads this consistency and ary inconsistency is immediately detectable as as an error. Parity checking ensures accurate transmission of data.

Peripheral	input/output equipment used to make hard copy of data such as typewriters, printers and CRT display. Also, a device adjacent to the central processor, such as graphic slides, a disc storage or tape storage unit.
Pneumatic-Electric Control Center (PECC)	enclosure for accommodating the remote elements of the conventional pneumatic-electric control system serving a HVAC system
Point	finite address of a field input/output device which may be discrete or analog
Point (Analog)	finite address having a variable value such as 456 psig, 60 gpm, 72°F or 20 ma
Point (Discrete)	finite address having a discrete value, such as on, off, opened and closed
Point Module	a logic card in a data-gathering panel
Printers	similar to a teletype model 35, Page Printer, wide carriage, pedestal-mounted, utilizing 10 characters per second, 72 character spaces per line, standard ASCII Code, continuous-duty rated for 5,000 hours, meantime between failures
Program	a series of input instructions and parameters which define in detail the computer steps necessary to perform an output function
Scan	to examine stored information for a specific purpose as for content and arrangement. To examine the status of input/output signals to determine whether data are being received or transmitted
Scan (Active)	to interrogate stored information on a continuous basis
Scan (Dynamic)	a system in which the CPU generates a zero signal to each point scanned and verifies the signal, regardless of the status of the point
Scan (Passive)	to interrogate stored information by exception and only when the point scanned changes state
Sensor	a device capable of evaluating the status or value of a contract closure or variable analog (e.g., a thermometer)
Software	the written programs or routines prepared to simplify programming and computer operations. Such routines permit the operator to use English or mathematics to communicate with the computer. Various programming routines supplied to facilitate operation of various assemblies, subroutine libraries, compilers, operating systems and industry application programs.
System	the entire operation, including software, hardware, sensors, transmission network, man-machine interface, management instructions and output reports
System Capacity	the number of points that the system is capable of monitoring and controlling

System Functions	operations that can be performed by the central control system, such as alarm monitoring, indication and command functions, alarm instructions, demand limiting and load shedding, energy management, start time optimization, alarm logging, system logging and fire management
System Status	the condition of a particular point of systems such as normal, abnormal, on, off, up, alarm, and overload
Trunk Wiring	the matrix or time-shared electrical wiring connecting the central processing unit (CPU) with the Data Collection Panels (DCP)

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